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INDEX, VOL. XXVIII.

November, 1906, to July, 1907.

All Abstracts are printed in Italics, and appear only under the headings Analytical Chemistry, Metallurgy, and Mining Decisions.

Adjustment of Bench Levels. By S. D. Bleich 109

ALUMNI AND UNIVERSITY NEWS.

Chemistry 407, 526
Civil Engineering 124, 407, 529
Drawing 407
Electrical Engineering 126, 529
Geology 242, 407
Mathematics 407
Mechanical Engineering 127, 407
Metallurgy 530
Mineralogy 533
Mining 123
Physics 407
Physics and Mechanics 127

Analytical Chemistry, Abstracts. By Elwyn Waller 226, 482

Acetylene as a Reagent 482
Acidimetric Estimation of Phosphoric Acid 483
Adulteration of Red Lead 494
Analysis of Mantles for Incandescent Lights 232
Analysis of Wulfenite 491
Antimony and Tin in Alloys, etc 488
Antimony—Electrolytic 229
Antimony—Volumetric 487
Arsenic 490
Arsenic and Antimony in Ores 489
Arsenic Separation 229
Arsenic Solution for Standardizing 487
Assay of Cyanide Solution from Gold Extraction 229
Babbitt Metal 230
Barium Peroxide 494
Beryllium Estimation 490

Beryllium—Separation from Aluminum and Determination 490
Boric Acid 235
Bromate Solution 487
Bromine Solution 487
Cadmium Determination 229
Chlorate in Sodium Nitrate 234
Chloride in Waters 492
Chlorides 492
Cobalt—Delicate Test 487
Cobalt Separations 487
Color Tests of Nitric Acid 236
Colorimetric for Gold 489
Colorimetric for Selenium 233
Commercial Tin 231
Control of Electric Copper Refining 490
Copper Titration 490
Cyanogen Iodide in Iodine 494
Decomposing Silicates 493
Delicate Reaction for Copper 228
Determination of Calcium 227
Distinguishing Dolomite from Calcite 484
Estimating Moisture 237
Extracting Thorium from Monazite Sand 233
Ferrous Iron 484
Fluorides—Etching Test 235
Fluorine-Iodometric Estimation 493
Formate Process for Separating Ferric Iron 486
Free Acid in Presence of Ferric Salts 227
Free Mineral Acids in Presence of Acetic 483
Furnace Gases 238
Gold or Silver—Quantitative 229
Hydrocyanic Acid 494
Hydrofluosilicic Acid 493
Hydrogen Sulphide 482
Indicator 487
Iodine in Mixtures of Halogen Salts 234
Iodine in Presence of Chlorine and Bromine 493
Lewis Thompson Calorimeter 494
Magnesium—Qualitative 227
Melting Point of Asphalt, Pitch, etc. 238
Mercury Ores 229
Mercury—Volumetric 490
Molybdenum 491
Nickel—Qualitative 227
Niobium and Tantalum in presence of Titanium 492
Nitrates and Nitrites 237
Nitric Acid in Nitrates 236
Nitrogen in Nitrocellulose 237
Osmium from other Platinum Metals 234
Potassium—Phosphotungstic Test 483

Preparing Chloric Acid as a Reagent 482
Preparing Rubber Samples for Analysis 226
Qualitative for Borax 235
Qualitative for Copper in Presence of Lead or Bismuth 228
Qualitative for Zinc 228
Reagent for Potassium 483
Separating Antimony and Tin 230, 488
Separating Barium from Calcium 484
Separating Beryllium from Aluminum and Iron 232
Separating Iron from Zinc 228
Separating Manganese from Nickel and Cobalt 227
Separating Tungsten from Tin 234
Separating Vanadium and Uranium 233
Separation of Arsenic, Antimony and Tin when obtained as sulphides, Qualitative 230
Separation of Zinc 486
Silica in Iron Ores Containing Alumina 493
Silicon in Presence of Silica 235
Silver Crucibles for Sodium Peroxide Fusions 226
Silver in Commercial Copper 228
Small Amounts of Copper in Water 228
Sodium Chloride in Commercial Tin Salts 487
Sodium Hydrosulfite in Gas Analysis 226
Sodium Phosphates—Acidimetric 226
Standard Sulphuric Acid 482
Standardizing Permanganate 226
Standardizing with Metallic Magnesium 483
Sulphates in Potable Water 236
Sulphide in Commercial Cyanide 236
Sulphur Acids 236
Sulphur Determinations 493
Sulphur in Insoluble Sulphides 493
Sulphur in Pig Iron 236
Sulphur in Pyrites 235
Tin and Tungsten 234
Tin—Qualitative 231
Titration of Hydrogen Peroxide 237
Tungstic Acid in Wolframite, etc. 491
Use of Filter Tubes 482
"Volatile Combustible" in Coal 238
Volumetric for Lead 229
Volumetric for Zinc 485
Zinc—Ferrocyanide Titration 484
Zinc—Na_2S Titration 484
Zinc Ores 485
Zinc—Precipitation of Small Amounts 484
Zinc Titration with Ferrocyanide 228
BEDELL, CHARLES H. The Design of Direct Current Motors 101
Bench Levels, Adjustment of. By Samuel D. Bleich 109
BLACK, ADOLPH. Hydraulic Formulæ: Development and Discussion 417

BLEICH, SAMUEL D. Adjustment of Bench Levels 109
BOOK REVIEWS:
A Treatise on Rocks, Rock-weathering and Soils. By George P. Merrill 248
Catechism on Producer Gas. By Samuel S. Wyer..... 132
Chemical Abstracts. Published semi-monthly. By the American Chemical Society through the Chemical Publishing Co..... 544
Clays, Their Occurrence, Properties and Uses, with Especial Reference to those of the United States. By Heinrich Ries 247
Construction and Care of Brick Pavements. By Ira O. Baker..... 544
Das Erdöl und seine Verwandten. By Hans Höfer 540
Die Untersuchung des Erdöles und seine Producte. By M. A. Rakusin.. 541
Electricity as Applied to Mining. By Arnold Lupton 245
Elements of Gas Engine Design. By Sanford A. Moss..... 542
Four Centuries of the Panama Canal. By Willis Fletcher Johnson.... 543
Geology of Western Ore Deposits. By Arthur Lake 248
Gold Mining Machinery, Its Selection, Arrangement and Installation. By W. H. Tinney 409
Handbook of Mathematics for Engineers and Engineering Students. By J. Claudel. Translated by Otis Allen Kenyon..... 130
Hydro-Metallurgy of Silver, with Special Reference to the Chloridizing Roasting of Silver Ores and the Extraction of Silver by Hyposulphite and Cyanide Solution. By Ottokar Hoffman 537
Lead Smelting and Refining, with some Notes on Lead Mining. Edited by Walter Renton Ingalls 410
Long Distance Electric Power Transmission: a Treatise on the Hydro-Electric Generation of Energy; its Transformation, Transmission and Distribution. By Rollin W. Hutchinson, Jr..... 411
Mechanics Problems. By Frank S. Sanborn 544
Mica and the Mica Industry. By George Wetmore Colles..... 129
Notes on Metallurgical Mill Construction. Edited by W. R. Ingalls.. 129
Principles of Copper Smelting. By Edward Dyer Peters..... 535
Rock Minerals: Their Chemical and Physical Characters and Their Determination in Thin Sections. By Joseph P. Iddings..... 539
Seven Follies of Science. By John Phin 542
Sewage and Sewage Disposal. By Professor Henry Robinson..... 543
Structural and Field Geology for Students of Pure and Applied Science. By James Geikie 246
Technical Dictionary, Volume 1, Machine Details and Tools. By K. Deinhardt and A. Scholmann 131
The Mineral Industry, Its Statistics, Technology and Trade, During 1905. Edited by Walter Renton Ingalls 244
Van Nostrand's Chemical Annual, 1907 545
BURR, WILLIAM H. Proposed Testing Laboratory of the Department of Civil Engineering 479
BURR, WILLIAM H. The Technical School and the University..... 141
Calculation of Chemical Equilibria. By K. George Falk..... 441
CAMPBELL, WILLIAM. Abstracts—Metallurgical 392, 502
Cantilevers, Influence Lines for Suspended. By Myron S. Falk..... 362
Civil Engineering, Proposed Testing Laboratory of the Department of

Civil Engineering. By William H. Burr 479
CLARK, WALTER G., and HERSCHEL C. PARKER. The Helion Lamp..... 471
Columbia Chapter Society of the Sigma Xi, Meeting of..... 523
Columbia University, Dinner to the Civil Engineers of..... 116
Constructing, Method of, the Foundations for the Trust Company of America Building, New York City. By Maurice Deutsch..... 459
Crystal Drawings, Stöber's Method of Making. By Austin F. Rogers..... 222
Design of Direct Current Motors. By Charles H. Bedell..... 101
Development and Discussion, Hydraulic Formulæ. By Adolph Black.... 417
DEUTSCH, MAURICE. Method of Constructing the Foundations for the Trust Company of America Building, New York City..... 459
Dinner to the Civil Engineers of Columbia University..... 116
Direct Current Motors, the Design of. By Charles H. Bedell..... 101
DOUGLAS, JAMES. Some of the Relations of Railway Transportation in the United States to Mining and Metallurgy..... 1
Drawings, Stöber's Method of Making Crystal. By Austin F. Rogers..... 222
Engineering Trips, Supplies for. By William Newbrough..... 387
Equilibria, The Calculation of Chemical. By K. George Falk..... 441
FALK, K. GEORGE. The Calculation of Chemical Equilibria..... 441
FALK, MYRON S. Influence Lines for Suspended Cantilevers..... 362
Fery Radiation Pyrometer, Principle and Operation of. By C. H. Wilson and Frederick Maeulen 353
Fossils, North American Index Fossils (part 2). By A. W. Grabau and H. W. Shimer 20, 150, 251
Foundations, Method of Constructing the, for the Trust Company of America Building, New York City. By Maurice Deutsch..... 459
GOETZE, FREDERICK ARTHUR, Dean of the Faculty of Applied Science..... 477
GRABAU, A. W., and H. W. SHIMER. North American Index Fossils, part 2. 20, 150, 251
Helion Lamp. By Walter G. Clark and Herschel C. Parker..... 471
Hydraulic Formulæ: Development and Discussion. By Adolph Black..... 417
Index Fossils, North American (part 2). By A. W. Grabau and H. W. Shimer 20, 150, 251
Influence Lines for Suspended Cantilevers. By Myron S. Falk..... 362
JACOBY, HAROLD. John Krom Rees 413
Lamp, Helion. By Walter G. Clark and Herschel C. Parker..... 471
Levels, Bench, Adjustment of. By Samuel D. Bleich..... 109
MAEULEN, FREDERICK, and C. H. WILSON. Principle and Operation of the Fery Radiation Pyrometer 353
Meeting of the Columbia Chapter Society of the Sigma Xi..... 523
Metallurgical Abstracts. By William Campbell..... 392, 502
A Wet Silver Mill 398
Alloys of Antimony and Tellurium and of Antimony and Selenium..... 518
Alloys of Antimony and Tin..... 519
Alloys of Copper and Arsenic 405
Alloys of Gold with Bismuth and Antimony..... 519
Alloys of Lead and Calcium 519
Alloys of Magnesium and Cadmium, Zinc, Bismuth, Antimony..... 520
Alloys of Magnesium and Silver..... 520
Alloys of Nickel and Antimony 518

Alloys of Silver with Thallium, Bismuth and Antimony 519
Alloys of Zinc and Iron 521
Aluminium 392
Aluminium—Bismuth and Aluminium—Tin Alloys 518
Ammonia—Copper—Cyanide Process 398
Antimony 392
Antimony—Cadmium Alloys 518
Antimony Industry 502
Antimony—Thallium Alloys 518
Arizona and Sonora 502
Arsenic 392
Art of Cutting Metals 510
Baggaley Pyritic—Conversion Process 394
Beehive Oven Construction 505
Belt Conveyor in Cyanide Plants 508
Bismuth 392
Blake-Dennison Weighing Machine 505
Blast-furnace Charging 394
Bristol Recording Pyrometer 515
Brittleness and Blisters in Thin Steel Sheets 399
Burning, Overheating and Restoring of Steel 400
Cementation 512
Cementation by Means of Gases 400
Chemical Action in the Acid Open Hearth Furnace 399
Chromium and Chrome Ore 392
Coal-Dust Firing of Reverberatory Matte Furnaces 394
Coke Oven Construction 505
Colorado Fuel and Iron Co 509
Comparison of American and Foreign Rail-specifications 511
Composite Metallurgical Vessels 505
Compounds of Manganese with Silicon 521
Constitution of Copper-Tin Alloys 519
Constitution of Iron-Carbon Alloys 516
Copper 393
Copper and Sulphur 406
Copper-Cadmium Alloys 519
Copper Converter Melting its Own Matte 504
Copper Deposits of New Jersey 393
Copper Mines of Japan 393
Cost of Smelting Copper Ore 504
Crushing and Grinding at Kalgoorlie 507
Crystallography of Iron 517
Cyanidation during 1905 396
Cyanide Plant, a New 506
Cyanide Practice at El Oro 506
Cyanide Practice at Kalgoorlie 507
Cyanide Practice at the Liberty Bell Mill, Telluride, Colorado 506
Cyanide Practice with the Moore Filter Press 507
Cyanide Treatment of Cupriferous Tailings by the Sulphuric Acid Process 398

De Lamar Copper Refinery 395
Decomposition and Formation of Zinc Sulphate in the Roasting of Blende 514
Deformation and Fracture in Iron and Steel 517
Determination of Matte 395
Development of Placer Gold-mining in the Klondike District, Canada.. 396
Early Use of Iron 399
East Helena Plant of the A. S. and R. Co..... 401
Effect of Copper in Steel 399
Electric Arc Applied to Pyrometry 515
Electric Furnace for Heating Crucibles 505
Electric Smelting of Iron 509
Electric Smelting of Sulfide Ore and Furnace Product Direct to Metal. 522
Electrolytic Precipitation of Bronzes 505
Electrolytic Precipitation of Gold from Cyanide Solutions..... 508
Equilibrium and Structures in the Iron Carbon System..... 516
Equilibrium Curves of the System Iron and Carbon..... 400
Equilibrium Diagram for Iron and Sulphur 521
Equilibrium Diagram of the Iron-Carbon Series 516
Etching Reagents for Steel Metallography 515
Experiments on the Metallurgical Behavior of a Mixture of Lead Sulphide and Calcium Sulphate 402
Federal Smelting Works, Alton, Illinois 402
Fuels, Refractories, Furnaces 505
Gaseous Fuels 505
German Technical Schools 522
Globe Plant of the A. S. and R. Co..... 402
Gold and Silver 395, 505
Gold Dredging in 1905 395
Gold Mill Construction 396
Great Boulder Proprietary Gold Mine..... 507
Grinding Pans Versus Tube Mills 397
Hardening of Steel 517
Hardness of the Constituents of Iron and Steel 518
Heat Balance Sheet of the Blast Furnace 509
Heat Treatment of Wire 511
Heyn's Experiments on Hardening and Tempering of Steel..... 517
Hughes Gas Producer 505
Huntington-Heberlein Process 402
Hydraulic Mining in a Cold Climate 396
Hydraulic Mining in California 396
Improvements in Rolling Iron and Steel 511
Industrial Future of Special Steels 406
Influence of Nickel and Carbon on Iron 511
Influence of Nitrogen on the Properties of Iron and Steel 399
Influence of Silicon, Phosphorus, Manganese and Aluminium on Chill in Cast Iron 400
Influence of Vanadium on Iron and Steel 511
Influence of the Condition of the Several Varieties of Carbon upon the Strength of Cast Iron 512

Iron and Steel 398, 508
Iron-Carbon Series of Alloys 406
Kjellin Electric Steel Furnace 509
La Cananea Mining Camp 503
Lead 400, 513
Lead and Arsenic 405
Lead and Silver 405
Lead Mattes 522
Lime-roasting of Galena 513
Lime-roasting of Nickeliferous Matte 403
Lungwitz Process of Zinc Smelting 514
Magdalena Smelter, Oaxaca, Mexico 513
Manganese 403
Manufacture of Tool Steel 510
Mathewson Blast Furnace 394
Matte Converting 504
Metallographic Research in the Foundry 515
Metallography and Pyrometry 404, 515
Metallurgical Accounts 514
Metallurgical Development on the Rand 397
Metallurgical Revolution in Guanajuata 505
Metallurgical Situation in France 509
Metallurgy at the Liege Exposition 404
Metallurgy of Copper in Chile 504
Metals and their Ferro-alloys used in the Manufacture of Alloy Steels. 400
Method of Smelting Butte Ores 394
Methods of Gold Extracting in Western Australia 507
Milan Exposition 404
Milling vs. Smelting in the Treatment of Tonopah-Goldfield Ores..... 396
Mineral Point Zinc Works 514
Mineral Production of Norway 393
Mining and Metallurgical Methods of the Waihi Gold Mining Co., New Zealand 398
Mining and Metallurgy in El Oro, Mexico 397
Mining Industry of Japan 393
Mixed Distillation and Combustion Gases..... 505
Modification of Antimony 502
Molecular Change in Hardening 399
Molybdenum 403
Mount Lyell Mining and Railway Co..... 503
Murray Smelter, Utah 402
National Plant of the A. S. and R. Co..... 401
New Blast Furnace for the Matehuala Smelter..... 394
New Denver Mint 508
Nichols Copper Works 395
Nickel and Cobalt 403
Nickel-Chrome Steels 510
Nickel-Silicon Steels 510
Nitrogen in Steel 399
Nodulizing and Desulphurization of fine Iron Ores and Pyrites Cinder.. 509

Non-ferrous Magnetic Alloys 522
Northern Iron Company's Blast Furnace 509
Notes and Comments on the Pyritic Process of Mount Lyell, Tasmania. 503
Notes on Improvements in Cyanide Treatment of Sands and Slimes.... 507
Notes of Travel in the United States. Rolling of Billets, and Merchant Bars 508
Notes on the Use of the Filter Press for Clarifying Solutions..... 508
Occurrence and Extraction of Gold in Sarawak, Borneo..... 398
Occurrence and Treatment of Gold Ore at Bidi, Sarawak..... 398
On Some Microscopic Effects Produced on Metals by Strain 518
On the Alloying of Copper with Iron and Iron-Carbon Alloys..... 406
On the Constitution of Cast Iron 516
On the Converting of Nickel Matte to Nickel by Oxygen..... 403
On the Distillation of Roasted Blende and Calcining Calamine 514
On the Formation of Fume and Furnace Deposits in Lead Smelting.... 514
On the Heat Treatment of Some High-carbon Steels..... 511
On the Influence of Certain Elements on the Separation of Graphite in Cast Iron 400
On the Influence of Silicon on the Iron-Carbon System..... 516
On the Iron-carbon System 406
On the Nature of Copper Mattes 522
On the Present Position of Our Knowledge of the Solidification and Cooling of Iron-Carbon Alloys 406
On the Theory of the Formation of Graphite 516
On the Treatment of Speissy Blister Copper 395
On the Volatility of Zinc Blende 514
Ore Treatment at the Combination Mine, Goldfield, Nevada..... 506
Ore Treatment at the Kalgurli Gold Mines 397
Other Metallurgical Methods of Pachuca 505
Pachuca 398
Palmerton Works of the New Jersey Zinc Co..... 404
Peregrina Mill, Guanajuata 397
Perth Amboy Plant of the American Smelting and Refining Co....395, 401
Pot-Roasting of Ore 514
Practical Application of Metallography in the Works..... 515
Practical Application of Microscopic Metallography in the Works..... 515
Preliminary Note on the Influence of Manganese on Iron..... 399
Preparation of Carbon-free Ferro-manganese 512
Present Position of Lead Smelting in Germany 513
Progress in Gold Milling in 1905 396
Progress in Gold-Ore Treatment during 1905..... 395
Progress in the Metallurgy of Copper in 1905..... 393
Progress in the Metallurgy of Zinc..... 404
Progress of the Gold Mining Industry of Western Australia..... 397
Progress of the Metallurgy of Iron and Steel in 1905..... 398
Proposed Method of Treating Sand Dumps 507
Proposed Process for Treatment of Zinc-Gold Slimes before Smelting.. 508
Pueblo Smelters 402
Pyritic Smelting 394
Pyritic Smelting Without Coke 394

Quaternary Steels 510
Quick Treatment of Cyanide of Black Sands 507
Rand Metallurgical Practice and Recent Innovations 506
Recent Copper Smelting at Lake Superior 395
Recent Improvement at Anaconda 394
Recent Improvements in Lead Smelting 401
Recent Innovations in Rand Metallurgical Practice 506
Recent Processes in Machine Moulding Practice 512
Recent Work on Industrial Alloys 405
Relation Between Type of Fracture and Microstructure of Steel Test-pieces 399
Savelsberg Process 403
Segregation in Steel Ingots 511
Silicides of Nickel 521
Silver and Arsenic 405
Silver and Silver Sulphide 405
Siphon Spout and Matte-trap, Combined 394
Slag Granulating and Conveying Device 505
Slime Treatment at Mount Boppy 397
Smelter Administration 514
Smelting at Kansas City 513
Smelting Rates in Nevada 513
Sodium-Lead, Sodium-Cadmium, Sodium-Bismuth and Sodium-Antimony Alloys 520
Solidification of Copper 404
South Kalgurli Co.'s System of Ore Treatment 397
Special Steels 406
Speed of Attack of Metallographic Reagents 516
Stamp Mill, a Modern 396
Stamp Mill and Cyanide Plant of the Combination Mines Co., at Goldfield, Nevada 396
Stamp Milling in Northern California 396
Study of Special Brasses 405
Sulphide of Antimony and Antimony 521
Sulphide, Selenide and Telluride of Tin 521
Tacoma Copper Refinery 504
Technical Progress in Blast Furnaces 509
Tempering and Cutting Tests of High Speed Steels 510
Tempering of Steel 517
Test of Hardness by the Brinell Method at the Brussells Congress 512
Theoretical Aspects of Lead-ore Roasting 402
Theory and Practice of Dephosphorization of Iron and Steel 399
Tin 403, 514
Tin Smelting at Launceston, Tasmania 514
Tool Steel, a Defective Bar of 406
Treatment of Silver-Lead Tailings by the Cyanide Process 508
Treatment of Speiss and Speissy Blister Copper at the Okerhutte, Germany 395
Treatment of Tin Wolfram Copper Ores at the Clitters United Mines 403
Tube Mill Lining 507

Tube Mill Practice 507
Tube Milling on the Rand 397
Tungsten 404
Use of Metallography in Detecting Spurious Coinage 405
Vertical Arc Furnaces for the Laboratory 505
Volume and Temperature Changes during the Cooling of Cast Iron 400
Washoe Plant of the Anaconda Copper Mining Co. in 1905 503
Work of Fournel and the Lower Limit of A_3 517
Works of the United States Zinc Co. at Pueblo, Col 404
Zinc 404, 514
Zinc and Arsenic 521
Zinc-Antimony Alloys 519
Zinc Industry in the United States 404
Zinc Industry in Silesia in 1905 404
Method of Constructing the Foundations for the Trust Company of America Building, New York City. By Maurice Deutsch 459
MILLER, EDMUND HOWD. By Robert Peele 133
Mining and Metallurgy, Some of the Relations of Railway Transportation in the United States. By James Douglas 1
Mining Decisions, Abstracts 389, 495
Abandonment of Claim 498
Adverse Proceedings. Proof of Title 389
Assessment Work 496
Assumption of Risk by Employe 391
Breach of Contract Due to Strikes 495
Damages. Failure to Produce Maps 389
Description of Placer Location 500
Determination of Mineral Land 497
Duty to Inform Employe of Danger 391
Extra Lateral Right 390
Failure to Perfect Location 390
Fraudulent Relocation of Claim by Lessee 498
Liability Involved in Removal of Culm 495
Liability for Condition of Mine Tracks 496
Liability of Innocent Trespasser 390
Miners' Responsibility for Accidents 499
Misrepresentation. Neglect to Rescind Contract 496
Necessity of Actual Discovery on Placer Ground 497
Negligence of Employer. Effect of Miner's Contract 390
Parallelism of End-lines 501
Proof Required of Abandonment or Forfeiture of Location 499
Proper Contents of Location Certificate 500
Right to Draw Oil from Adjoining Land 499
Right to Railroad Sidings 389
Rights of Joint Owners in Tunnel 495
Rights of Locator and Purchaser 496
Rights of Locators: Incomplete Location 499
Rights of Purchase of Minerals in Place 497
Rights to Swing Claim during Location 389
Safety of Working Places 390

Severance of Title to Minerals 497
Sufficient Description of Claim 500
Time Within Which Constructive Trust May be Enforced 497
Two Mine Openings to Surface 495
Warning to Employes 499
What Constitutes Valid Discovery? 498
Motors, The Design of Direct Current. By Charles H. Bedell..... 101
NEWBROUGH, WILLIAM. Supplies for Engineering Trips..... 387
Notes on Three-phase Traction. By Gerard B. Werner..... 376
North American Index Fossils, part 2. By A. W. Grabau and H. W. Shimer. 20, 150, 251
PARKER, HERSCHEL, C., and WALTER G. CLARK. The Helion Lamp 471
PEELE, ROBERT. Edmund Howd Miller 133
PERKIN, SIR WILLIAM HENRY 239
Principle and Operation of the Fery Radiation Pyrometer. By C. H. Wilson and Frederick Maeulen 353
Proposed Testing Laboratory of the Department of Civil Engineering. By William H. Burr 479
Pyrometer, Principle and Operation of the Fery Radiation. By C. H. Wilson and Frederick Maeulen 353
Railway Transportation in the United States to Mining and Metallurgy, Some of the Relations of. By James Douglas 1
REES, JOHN KROM. By Harold Jacoby 413
ROGERS, AUSTIN F. Stöber's Method of Making Crystal Drawings..... 222
SEVER, G. F. Frederick Arthur Goetze, Dean of the Faculty of Applied Science 477
SHIMER, H. W., and A. W. GRABAU. North American Index Fossils, part 2. 20, 150, 251
Sigma Xi, Meeting of the Columbia Chapter 523
Some of the Relations of Railway Transportation in the United States to Mining and Metallurgy. By James Douglas 1
Stöber's Method of Making Crystal Drawings. By Austin F. Rogers..... 222
Supplies for Engineering Trips. By William Newbrough..... 387
The Technical School and the University. By William H. Burr 141
Three-phase Traction, Notes on. By Gerard B. Werner..... 376
Traction, Notes on Three-phase. By Gerard B. Werner..... 376
Trust Company of America Building, New York City, Method of Constructing the Foundations for the. By Maurice Deutsch..... 459
WALLER, E. Abstracts—Analytical Chemistry 226, 482
WERNER, GERARD B. Notes on Three-phase Traction 376
WILSON, C. H., and FREDERICK MAEULEN. Principle and Operation of the Fery Radiation Pyrometer 353

VOL. XXVIII. No. 1. NOVEMBER, 1906.

THE

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CONTENTS:

Some of the Relations of Railway Transportation in the United States to Mining and Metallurgy. By James Douglas, LL.D..... 1
North American Index Fossils, II. By A. W. Grabau and H. W. Shimer..... 20
The Design of Direct Current Motors. By Charles H. Bedell 101
Adjustment of Bench Levels. By Samuel D. Bleich 109
Dinner of the Civil Engineers of Columbia University..... 116
Alumni and University News..... 123
Book Reviews..... 129

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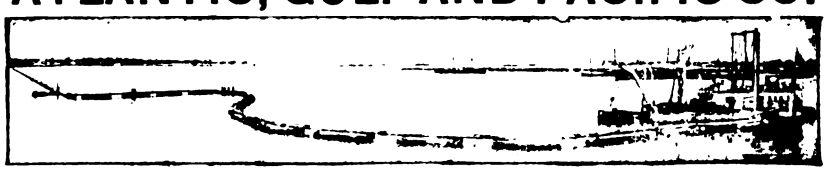

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SOME OF THE RELATIONS OF RAILWAY TRANSPORTATION IN THE UNITED STATES TO MINING AND METALLURGY.*

BY JAMES DOUGLAS.

We can best appreciate the part the railroad has played in the industrial progress, made by this country, by comparison with one of our industrial rivals — England, for example. The railroad, as a factor in commercial life, came into existence on both sides of the Atlantic in 1830, when the Liverpool and Manchester Railroad ran its first train, and Peter Cooper's "Tom Thumb," the first locomotive built in America, drew a car upon rails out of Baltimore. We have no record of the miles of track in 1830, but several short stretches of railroad in New York, New Jersey, Pennsylvania, Vermont and North Carolina, in 1831, added together, gave a length of only ninety-five miles.

But mining and metallurgical operations were much more active on the little island than on our big continent. When the railroad arrived to assist in reversing the industrial status, the insular position and the configuration of Great Britain enabled her to take advantage of her mineral resources; while our population, scattered even then over almost half our section of the continent, with few canals or no really cheap means of intercourse or transportation, could not have built up any large metallurgical enterprise, no matter what the natural resources might be.

England's production of pig iron was then 677,417 tons but the success of the Liverpool and Manchester Railroad created a railroad-building mania so acute that before 1840, 299 acts, authoriz-

* An Oration delivered by Dr. James Douglas before the Graduating Class under the Faculty of Applied Science, at Columbia University, June 12, 1906.

ing the construction of 3,000 miles of railroad had been passed by, or were before, Parliament; but the 3,000 miles had not been actually built. The stimulus thus given to the iron trade was, however, such that the production of iron rose in 1840 to 1,396,400 tons. We thus get the first example of the tremendous reciprocal influence which railroads have exerted upon the iron trade.

Here, once started, our progress in railroad building was rapid, for by 1840 we had 2,818 miles of road in actual operation, or more than England. But in 1830, when neither country possessed facilities for inland transportation, England far surpassed us in metal production. There were, as I have said, produced in Great Britain 678,417 tons of pig iron. She mined about 50,000 tons of coal, made 11,500 tons of copper, about 58,000 tons of lead, and 4,400 tons of tin. Since then her railroad mileage has increased to 22,700, her production of pig iron to 9,000,000 tons, her lead production, however, has declined to 20,000 tons, her production of copper has become a negligible quantity, and her tin production has not increased.

Meanwhile our railroad mileage has grown to 212,000, as against 23 miles in 1830; our pig iron production from 135,940 tons to 22,822,380 tons; our coal from 209,000 to 314,562,880 tons; our copper from nothing to 462,000 tons, and our lead from 10,000 to 322,886 tons.

That England, without railroads, should have occupied so conspicuous a position in the metallurgical world, while we, with a population at that date of only three and a half millions less than that of England, Scotland and Wales, produced so much less, was due to her geographical configuration, and the distribution of her important metallic and non-metallic deposits. England, Scotland and Wales are included in a long, narrow island, which is so deeply indented by the estuaries of navigable rivers that the average width from navigable water on the west coast to navigable water on the east coast does not exceed 250 miles. And if we except the lead of Derbyshire, all of Great Britain's coal and mineral wealth lies sufficiently near navigable water to have rendered her in early days prosperous without the aid of railroads. The coal fields of Durham and Northumberland are on the seashore, or intersected by the Tyne, The Clyde and the Firth of Forth cut into the Scottish coal basin, which extends across the narrow neck from the Atlantic Ocean to the North Sea; and the Welch coal field lies on or near the Bristol

Channel. The Cleveland iron ores are close to the east coast, and, unlike any of our own great ore bodies, except those of Alabama and Tennessee, are almost in contact with the fuel suitable for their reduction. On the west coast are the rich and pure hæmatites which give industrial life to Barrow-on-Furniss. The coal measures reach the sea near-by at Whitehaven, Cumberland. The copper and tin of Devon and Cornwall have been mined from time immemorial on a narrow peninsula washed by the Atlantic and the English Channel. England would, therefore, owing to her insular position and conformation, have retained her metallurgical prominence without the railroad. Its introduction has been in fact one cause of her relative decline, inasmuch as not being as essential to her growth as to that of her great rivals, the railroad has therefore not been developed with the same energy as in this country and in Germany.

Turning to our own position, as metal miners and workers, in 1830, the year of the railroad's advent, when the census records were still given by value, we made $4,757,403 worth of pig iron, of which Pennsylvania contributed $1,643,702. Taking Swank's value of pig at $35, the total production of pig was 135,940 tons. Our copper industry did not assume appreciable proportions till years afterwards — the first recorded production being 150 tons in 1846. But the lead mines of Missouri, which had been one of the tempting baits to induce dupes of an earlier day to invest in Thomas Law's Mississippi Bubble, were in 1830, with small contributions from Wisconsin, producing all of the 8,000 to 10,000 tons which we were then making. These regions were sufficiently near navigable waters to be accessible.*

If we advance to the sensus of 1840, the first in which quantities are recorded instead of values, we are struck by the fact that the advent of the railroad does not seem to have stimulated the manufacture of iron here as acutely as it did in England. The production of 135,940 tons increased to only 286,902 tons — an increase of 150,963 tons, while in England it rose from 677,417 to 1,396,400 tons. Though most of the roads were laid with strap rails, T rails were already supplanting them; but none were rolled in this country till 1844.

* According to Warden, in 1810 the furnaces, forges and bloomeries in the United States amouted to 530, of which the State of New York furnished 69. But many of the important seats of the industry of that day have disappeared. The Franconia Works in New Hampshire, established in 1810, are particularly mentioned as employing a capital of $100,000. The Vergennes Works in Vermont promised to be very important. He tells us that the price of bar iron at that establishment was $140 per ton.

And the concentration of the iron industry, was not notable, the Alleghanies not having yet been surmounted by an iron road. In that year the 286,903 tons of pig iron were made in 804 blast furnaces, located all over the inhabited country from Maine to Michigan, — the average production per furnace per day being only 19.40 cwt. Of these 213 were in Pennsylvania. There were almost the same number of bloomeries, forges and rolling mills, making only 197,233 tons of bars — Pennsylvania producing but 87,244 tons. Minnesota, which now stands first and foremost as an iron ore producer, was still an undefined part of that great wilderness known as the Northwest Territory; but Michigan had been for four years admitted to the privileges of statehood and was a producer of iron, and finished iron products, using charcoal as fuel. The Southern States made iron in small quantities for local use; but New York, New Jersey and Pennsylvania were the most active manufacturers.

Though Pennsylvania was at the head of the list of iron producers, she occupied that position by virtue of her possession of iron deposits within her own limits of such size and richness that they still sustain centers of great local activity. The Cornwall ore banks maintain the credit of the famous South Mountain Range, and hold their own as one of the great iron mines of the country. Their production in 1903 was 401,469 tons, though, with the iron industry generally, they fell off in 1904. There were in Allegheny County, where Pittsburgh is now situated, in 1840, 28 charcoal furnaces, producing 6,584 tons of pig iron and 12 bloomeries and forges, producing 28,100 tons of bars. The large amount of finished iron was due to the fact that already the fine coals of that district attracted pig made elsewhere to Pittsburgh. Pennsylvania occupied prominence by virtue of her home supply of ore, and Pittsburgh was the heart of Pennsylvania's iron trade by reason of her coal. Today Pennsylvania's furnaces make half the iron of the country, but not from her own ores, for in 1905 her furnaces poured forth 10,599,107 tons of pig iron, but her mines produced only 810,000 tons of ore.

The explanation lies in the potency of transportation. Pittsburgh possesses coal and coke, Michigan and Minnesota the largest, purest, and, considering their quality, the most cheaply mined ores in the country. It is at present cheaper to bring the ore to the fuel, and to the people who buy and consume the iron, than to take the fuel

to the ore and carry back most of the finished product. And the complete revolution effected within the last half century in this and every other great branch of metallurgy has been brought about by the railroad and steamboat. Of the fifty million tons of ore treated in this country last year 34,353,456 came from Lake Superior, and by far the largest shipments were from the Mesaba Range, 1,025 miles distant from Pittsburgh, where the ores were reduced.

In deciding where it is most economical to reduce ore to metal, the cost of transporting the raw material, the fuel and the finished product to the most profitable market are the determining factors.

There are some strange contradictions of this rule, as for instance, the persistency with which the copper and brass trade adhere to the Naugatuck Valley in Connecticut. It has been an old industry there, for Warden in 1819 says "Metal buttons have been manufactured at Waterbury and New Haven of which the annual amount has been estimated at $100,000." And there are ill-suited locations of some of our large iron works which were started originally near some small iron deposits now exhausted, or on a water power, too trifling to be used to-day, but which survive as geographical anomalies because the necessity is not yet urgent enough to oblige the owners to wipe out the large capital invested. But our more progressive corporations are taking this radical step, as instanced by the owners of the Lackawanna Steel Co., whose owners have transferred their works from Scranton to Buffalo, while their name alone perpetuates their former prosperous existence in the heart of Pennsylvania. If we assume for instance that at present two tons of Lake Superior ore make one ton of pig iron, and that one ton of fuel is consumed in reducing them to one ton of pig, and this pig iron is used up in the east, then two tons of cheaply handled ore are transferred to Pittsburgh, whereas if that ore were reduced at the mine, one ton of fuel, whose transportation, owing to its bulk, is more costly than that of a ton of ore would have to be carried from Pennsylvania or Ohio, and one ton of pig of high value, and therefore commanding a higher freight rate, would of necessity be shipped back to the eastern market. Under either condition four tons of freight must be shipped to lay down a ton of pig in Pittsburgh — two tons from west to east, and two from east to west; but the eastbound ore can be handled with less loss and at less cost than coal and coke could be carried west and pig iron east. Therefore, up to the limit of the demand of

the eastern market for pig iron, it is cheaper to make it of Lake Superior ore in Pittsburgh than to make it on Lake Superior. But the western market is rapidly growing, and new works are being laid out on Lake Michigan, rather than either in the heart of Pennsylvania or on Lake Erie; for both Michigan and Minnesota ore can be laid down more cheaply on the shores of Lake Michigan than at any point in Pennsylvania or Ohio; and though the great central coal basin does not yield a good coking coal, it does produce cheap fuel for converting pig into finished product. Last year the shipments of iron ore from Lake Superior amounted to 34,353,456 tons. Of this 84.4 per cent. were transferred inland by rail to ports on Lake Erie; the balance, 5,369,098, was shipped to points on Lake Michigan.

As, however, the west grows — and the west is shifting always to points still further west, its demands for iron grow almost more rapidly than the east, and the center of manufacturing will continue to move westward. This tendency we see in the rapid expansion of the only large iron and steel organization west of the Missouri — the Colorado Fuel and Iron Co. While in 1900 its furnaces at Pueblo made only 150,204 tons of pig iron, they made in 1905 407,774 tons. And yet these furnaces depend on long distance freight for their supply of ore. Some of it comes over a haul of 700 miles from southern New Mexico; and much of it comes from Wyoming, and distant points in Colorado. But the fuel supply is near at hand in the Trinidad coal field.

We know of no iron deposits in the west comparable in size to those on Lake Superior, but there are many which can be profitably worked. And though within our own territory west of the Great Salt Lake Basin we have no good coking coal, our neighbors to the north can supply it, or we can draw it from New South Wales, which already has shipped coal for railroad purposes to the Pacific Coast. From our other neighbor on the south, should iron and steel works be started on the west coast, we can draw ore from the large deposits said to lie on the very seashore near Acapulco; for distance is being rapidly obliterated by steam, and by it also let us hope international selfishness and commercial exclusiveness. Literature is tending to unify the race and commerce, through the railroad and steamboat, is another beneficent force working to the same end. As people come to know one another better, under a process of natural selection, they will surely imitate and adopt

each others better qualities, and without losing their national idiosyncrasies, acquire a higher cosmopolitan character.

The marvellous feats which two generations of engineers, in handling steam and electricity, has enabled us to perform, may not be duplicated by equal progress during the next half century; but it goes without saying that but for our transportation facilities we would not occupy in the world's race the same advanced position we have acquired today, for the very vastness of our country, and the actual distance, from one another and from population of our resources, would have rendered many of them valueless. But, given control of steam, the great size of our mineral deposits and the long distance our continental areas require that we transport material, has inspired our transportation engineers to work on a larger scale than their fellow craftsmen across the sea. We handle longer trains, with larger cars, and as a rule at a much lower rate of freight than they do. Otherwise, neither our miner nor our metallurgist could perform the duty required of them.

Take for instance the cost of transporting a ton of iron ore from Lake Superior to Pittsburgh — 70 cents from the mines to Duluth, a distance of 80 miles; 75 cents for 1,000 miles by steamer to Cleveland (though the rate has been as low as 57 cents, and though, when the first shipments were made from Michigan in 1856, the rate was $3.00); then $1.18 from Lake Erie points to Pittsburgh, a distance of 135 miles—making the total transportation $2.63 for 1250 miles, including transfers.

Or take the rates $10 at which copper is transported from Montana to the Atlantic, a distance of nearly 3,000 miles. Soft coal is carried by eastern roads at about a half cent per ton a mile, but the rate on some western roads is as low as 40 mills a ton per mile. Nor is it only in the iron trade that low rates of carriage have helped us metallurgists.

The necessity of low fuel rates to economical metallurgy is obvious, especially when treating ores such as those of copper, whose percentage of valuable metal is so low that, even after water concentration, as many as twenty tons of charge are probably smelted on an average to yield one ton of copper. In such cases the fuel must be carried to the ore—not the ore to the fuel, as when smelting rich iron ores. At the Copper Queen Works in the early days the cheapest coke was Cardiff Patent Pressed brought round the Horn in wheat ships to San Francisco. It costs more than three

times the price at which New Mexico or Colorado coke is now delivered, after a railroad haul of from 800 to 1,000 miles. Coal for steam generation was then so costly that the country was swept clear of its scanty accessible forests. For raising steam crude oil is now brought in from Texas and California at a freight rate not exceeding three-fourths cent per ton mile; so that at one smelting works in southern Arizona 700 miles away from the nearest coal, or available petroleum wells, power is generated at a cost for fuel, maintenance and all expenses, of $79 per h. p. per year. Montana draws its coke largely from Pennsylvania, or from coke ovens on Lake Superior, fed with Pennsylvania coal, the fuel travelling over 2,000 miles from the pits to the furnaces.

While complaint may be made against some railroads for charging exorbitant rates on coal, our western roads are certainly not culpable, or Montana would not be able to turn out in metallic copper about one-fifth of the world's total, and Arizona about one-seventh of the world's total though both are situated in the heart of a continent, and between 2,000 and 3,000 miles distant from the point where their crude product is refined and marketed.

The interdependence of mines on railroads and of railroads on mines is best appreciated by some familiar examples of what each does. Butte, both the town and the great Butte Mines, are situated on a mountain side facing a valley beneath whose surface water can be reached in any quantity and at all seasons only by wells, but where none flows. The two great corporations operating there have been obliged, therefore, if they were to concentrate mechanically their large tonnage of low grade ore, to transport their ores to water. A site 26 miles distant was selected by the Anaconda Co., and thither to their new Washoe Works are carried daily from Butte, of their own and custom ore, about 9,000 tons at a cost of abbut $5.00 per car, or 14 cents per ton. As the ore contains less than three per cent of copper per ton and $1.29 in gold and silver, a haul of that length would be profitable only if carried at such low rates of freight. The other large company, the Boston and Montana Co., sends its ores 170 miles to Great Falls, where, however, the company has the advantage of water power.

The mining, transportation and smelting operations of our large corporations are on a stupendous scale, but the transportation is as essential an item in the result as the mining and smelting. For the United States Steel Corporation there were handled last year

18,486,556 tons of Lake Superior ore, and they themselves manufacture 12,242,909 tons of coke, which must have used up 20,000,000 tons of coal. This coal production is exclusive of 2,204,950 tons mined by themselves alone. For flux they use 4,000,000 tons of limestone. About 38,000,000 tons of freight, therefore, as ore, fuel and flux, must have been transported, half of it for over an average of 1000 miles, in addition to 10,000,000 tons of finished product for a shorter distance. A total of about 48,000,000 tons of freight were contributed by this single corporation. As it made only 9,940,799 tons, out of 22,992,380 tons of pig iron made in this country, or 43 per cent. of the whole, the total tonnage moved for a longer or shorter distance by the iron smelting industry must have been approximately one hundred and nine million tons.

An interesting instance of the facilities which transportation gives the metallurgist is afforded by the shipment of copper matte from Tennessee to the heart of Mexico, where it has been used to collect gold and silver from dry ores in the furnace and converter, and then returned for electrolytic refining and separation to the United States. Copper bars come from New Zealand to be refined here, and the refined product is returned to Europe for consumptions, for we ship abroad about 40 per cent. of our production. But for cheap carriage, often for long distances, of ore necessary to make a profitable mixture in lead and copper furnaces, many a district would be unexplored and unexploited. Till recently, for instance, the mines at Globe, Arizona, languished for want of sulphur and iron flux, and could barely make a million pounds of copper a month. But the railroads, appreciating the needs of the miner, and appreciating what is their own true interest, published a low ore tariff which enabled pyrites to be imported from distant districts where it is in excess; and as a result the production rapidly rose to three million pounds a month.

The copper industry, as compared with the iron trade, if gauged by the quantity of copper produced, is insignificant; but if measured by the ore raised in making a ton of copper, it assumed very different proportions. Instead of two tons of ore to the ton of metal, as in the case of iron, the average of ore mined, previous to water concentration, is more nearly forty tons, and therefore there are handled, to make our 460,000 tons of copper, about 18,000,000 tons of ore. Though this is not carried the same distance that iron ore is carried to fuel, nearly all of it is moved by steam for a

longer or shorter distance; and as about four tons of fuel are consumed to make one ton of copper, nearly twenty million tons of freight must be carried by the railroads to enable us to maintain our position in the copper world.

Without going into the economies of railroad rates, I would remind you that the low rates at which are carried these large quantities of low grade freight, on which the very existence of our large metallurgical industries depend, could be given only if supplemented by higher rates on higher class freight. And the very remunerative wages given miners and mill workers, and the high standard of their living, gives the railroad a large proportion of such profitable traffic. For instance, on a railroad with which I am connected, and which depends almost exclusively for its traffic on mines, the proportion of the different classes of freight is approximately as follows:

Ore,	49 per cent.	83 per cent. of traffic is carried at a very low rate.
Coke,	16 per cent.	
Coal and Petroleum,	3 per cent.	
Lumber,	8 per cent.	
Copper bullion,	7 per cent.	
Merchandise, fodder, etc.,	17 per cent.	at a higher rate.

Our western copper industry, like our iron industry, sprang into life on the touch of the railroad. Not until the Southern Pacific approached Arizona in 1880 was any notable copper made there, and the railroad alone galvanized Butte within a year afterwards into activity. And today our increasing production of that much sought after metal is due either to railroad extension into new regions or to lower freight rates over existing railroads. For our railroads have been learning that their prosperity depends on the healthy growth of the industries along their lines, and that these industries can be starved to death by high freight rates, or fed into lusty vigor by encouragement. I venture to think that none of us — miner or metallurgist — will often be driven to take advantage of any of the useful but drastic clauses of the Rate Bill which both Houses are so busy framing for our benefit. If we have a grievance, it will be easier to make the railroad traffic manager understand it and induce him to apply the remedy than to explain the intricacies of our case and depend for relief on a Commission in Washington. The railroads may not have been always in the past as far sighted as their customers, and their officials have not

always strictly obeyed the laws. But in as much as some of the most energetic, as well as the most able men in the country, now control them, if the public will not give them credit for common honesty or patriotism, it cannot deny them the vice or virtue of self-interest (call it selfishness if you will) and this, not favoritism nor legislative compulsion, induces them to foster the great industries dependent on their road. Moreover, and the rule has proved to be almost of universal application, the small shipper benefits by the advantage secured by his big wholesale neighbor, and enjoys rates which otherwise his own scanty traffic would not permit the railroad to give him; for low freights are dependent on large quantities carried, and the enormous bulk of our business is one of the principal reasons why our railroads can furnish such cheap transportation. It would be foreign to my purpose and improper in this place to discuss the accusations brought against the railroads, or rather against their officers, of fraud and favoritism; but it is not improper to direct attention to the extraordinary courage, energy and skill, as well as amount of capital which have been put into the building up of our stupendous railroad system, and to its vital influence on all our great industries, which have as a general rule, developed with the same rapidity as the railroads, on which they depend. Any check, therefore, given to the legitimate expansion of our railroads by ill-advised legislation, and by creating disturbance of public confidence, must react sensitively, not only on railroad securities, which is a small matter, but on our farming, our mining and all the other branches of national industry which depend on railroad transportation, and on whose prosperity conversely railroads depend.

And it is rather remarkable that, considering the scrutiny to which railroads are subjected, the intense competition in seeking business, not only between the railroads as corporations, but as between the subordinate officers and departments of each road, that so few suits have been brought and so few convictions obtained for breach of the existing laws. There are 1,400,000 railroad employes, all, as a rule, eager to advance their interests by furthering the prosperity of the corporation which they serve, and the corporation is responsible for any improper means that any of them may employ to attain that end.

There remains a product of the miner's skill upon which, above all others, the commercial and political welfare of the country

depends. I refer, of course, to coal. Fortunately, nature has not only been lavish of this gift, but has scattered it so widely that every great section has received its share. Moreover, in most localities the coal beds are so accessible and are deposited so horizontally that it can be mined much more cheaply than in any of the active industrial centers of Europe. The effect of this cheap fuel on our mining and metallurgical industries has been already referred to as one reason for the concentration of our most important industry — that of iron and steel making — at localities where fuel is exceptionally cheap. But there are other and more important phases of this subject which have a profound national bearing.

Of the 249,612,420 tons of bituminous coal mined in 1904 —

Tons.					
142,681,714,	or 57	per cent.	came from	Middle States	— Maryland, Ohio, Pennsylvania, West Virginia.
70,703,161,	" 28	"	"	Western "	— Colorado, Illinois, Indiana, Iowa, Kansas, Michigan, Missouri, Montana, Nebraska, North Dakota, Wyoming.
4,308,312,	" 2	"	"	Pacific . "	— California, Idaho, Oregon, Utah, Washington.
31,486,852,	" 13	"	"	Southern "	— Alabama, Arkansas, Georgia, Indian Territory, Kentucky, New Mexico, North Carolina, Tennessee, Texas, Virginia.

Now, if we distribute the density of railroad traffic, measured by the tons of freight carried one mile, over the same section, we find that density to be —

Tons.							
86,909,756,058	tons of freight	carried	1 mile	in Middle States,	or 50	per cent.	of total.
51,276,332,531	"	"	"	Western States	" 29	"	"
8,902,279,490	"	"	"	Pacific States, where petroleum is largely used,	" 5	"	"
27,231,621,498	"	"	"	Southern States,	" 16	"	"
174,522,089,577,					100	per cent.	

Of the 250,000,000 tons of coal mined, only about 58,000,000 are consumed by the railroad. Such parallelisms cannot be accidental, and while it shows how necessary coal is to the life of the nation, and how necessary, therefore, it is that all barriers against

its free distribution be removed, it at the same time proves that coal mining and railroading are such allied industries that they cannot very well be divorced.

Moreover, if the ratio of coal produced in each great section of our land bears so intimate a relation to the total traffic of that section, any disturbance of traffic by the imposition of rates, which would hamper manufacturing industries, would immediately tell upon the consumption, and therefore the production of coal, and *vice versa* any great rise in the price of coal through depressing manufacturing, would tell at once on the traffic. As, however, both traffic and coal mining not only maintain the ratio, but both increase rapidly in quantity, the inference is that railroads, in the matter of rates and general facilities for transportation, keep pace with the demands of the coal miner and the requirements of the manufacturing public, on whose activities the density of traffic depends. If the railroad should transgress, as they are generally supposed to do, punishment in loss of general traffic would as soon overtake them as punishment at the hands of the Interstate Commerce Commission.

But cheap fuel and cheap transportation have destroyed industrial sectionalism.

Each great group of states, as we have seen, produces independently its coal requirements and its railroads and industries generally are supplied from its own mines. The Pacific coast and the Southeastern Atlantic coast are most scantly endowed with coal, but on the other hand have abundant petroleum resources, though for metallurgical purposes, the western states sometimes draw coke from other regions. Were it not for this comparatively uniform distribution of fuel, railroad transportation would of necessity be higher, and all interests, especially metallurgical and manufacturing, would suffer. As it is, the old economical divisions into manufacturing New England and northern seaboard states, into the southern cotton growing states, and the western wheat raising states, have disappeared, and with this disappearance has vanished that diversity of interest, involving political dissension, which was so marked and dangerous a feature of national life before the War of Secession. The coal of the southern states has facilitated the introduction of cotton spinning and of other manufactures which give diversity of and a higher grade of employment to the negro population than hoeing corn and picking cotton. Every western

state, even those west of the Missouri is becoming a hive of industrial manufacturing life, owing to cheap coal. New England alone, largely due to her distance from coal, is making less comparative progress along these lines than other sections, as she is shut off by tariff partition from her nearest and natural coal supply, that of the maritime provinces of Canada.

Thus has this great coal industry, to whose development transportation is as much an element as mining become a prominent factor in our national life.

The action of a few railroad officials and coal mine owners, or the policy of some coal roads, may require that further safeguards be erected for the protection of the public, inasmuch as the above consideration and figures conclusively demonstrate that of all the vast interests of the country, the mining and the distribution of its coal is the most vital to individual and national well-being. But on the other hand any reckless interference with the machinery by which such beneficent results have been brought about, and are now being conferred on the public, may bring about disturbance to trade which it may be more difficult to remedy than it was to create.

The embarassment arising from a plethora of business is often as great as that which arises from its paucity, and this presents another phase of the coal situation which may explain some of the irritation against the coal roads. A railroad's equipment is approximately adjusted to the volume of its traffic, but when as sometimes happens our industries grow with abnormal rapidity, the demands on the railroad outstrip not only their material resources, but the human endurance and human skill of their employes. To take as a single instance, the coal cars necessary to handle the coal output of 1901, which was 261,874,830 tons, were probably sufficiently in excess of actual requirements to handle that of 1902, which increased to only 269,117,177 tons; but when our coal production jumped in 1903 to 319,069,229 tons, there was inevitably a car shortage. In 1904 there was a slight falling off in production, but when in 1905 it reached suddenly the extraordinary output of over 373,000,000 tons, all mines but those which owned their cars must have suffered at the hands of the underequipped railroads. And at such a crisis relief cannot be readily obtained, as the car manufacturers have orders booked a year and more ahead. These conditions, which are peculiar to

the commercial vicissitudes of this country, generally, and fortunately, in the direction of increased prosperity, throw a strain on the railroads which the public at large can hardly be expected to appreciate.

There is one more subject bearing on the relation of mining and railroads to which I wish to draw your attention, and that is also statistical. The intimate relation of the railroads to our great mineral and metallurgical industries — iron and steel — is illustrated by the parallelism between the extension of the railroad and the increased production of the metal. In 1840 there were 4,535 miles of railroad in operation and there were made 256,100 tons of pig iron. By the end of the century there were 250,142 miles of track, including double and single, and the production of our 200 blast furnaces was 13,620,703 tons. Fifty-three as a multiplier approximately represents the increase in both branches of industry. Since then the mileage of our steam roads has not kept pace with our iron production, but if to the steam road mileage of today be added about 30,000 miles of recently completed urban and interurban roads, 70 as a multiplier, instead of 53, represents ayproximately in both spheres of activity the still more intense energy exerted within the last few years. A similar parallelism may be traced between all branches of metallurgical industry. During the last ten years, when copper has been used so extensively in both electricity and architecture in association with iron, one ton of the rarer metal has been used to 83 tons of the more abundant, and this proportion has varied only slightly from year to year.

If we recede in our comparative study beyond ten years, we find that the quantity of iron in proportion to copper between 1886 and 1892 consumed in this country was much greater, viz., 97 tons of iron instead of 83, to one ton of copper. The increased use of copper in architecture and electricity explains its relatively, as well as its absolutely, greater consumption. But whereas more copper per ton of iron is now used than formerly, less lead is consumed copper generally replacing it in architecture. Zinc has maintained to iron a very steady ratio. This dependence of every metal on every other, of all on coal, and of both coal and the metals on transportation forms one of the chains of relations which link together the elements of our industrial life, as intimately as nature binds in dependence and interdependence all

matter and force, not omitting ourselves though we often struggle to liberate ourselves from its clutches. In fact, in watching the efforts of men to regulate their lives by legislation, one cannot help comparing the ease with which, without interference, a large city like our own is fed and clothed, under some natural law of supply and demand, with the great difficulty which the commissariat of the most systematic of governments finds in feeding and clothing an army of a half a million men. And one wonders whether we are not nowadays taking a great deal of trouble to correct by violent interference evils which would cure themselves.

The vast scale on which our continent is built and the abundance with which its resources are stored, both on its surface and below ground, has exerted an influence over the national character by stimulating the emotions and imagination of almost every section of the people. One effect has been to excite such faith in its illimitable possibilities that both our manufacturers and metallurgists are willing to provide for anticipated business at large outlay on a scale from which our foreign and more prudent competitors shrink. And there is not a railroad manager in the country who would not run his road through an uninhabited desert in full confidence that it contains resources which it only needs the transportation facilities he will provide to induce others as sanguine as himself to develop or unearth. This is peculiarly true of the west where every man is a fanatic as to his own capacity and the value of his property, and where this sublime self-confidence is as epidemic as mountain fever and soon attacks the stranger.

But there is danger in this laudable pride of country and in this over-weaning self-confidence, for, vast as our resources are, they are not inexhaustible. Mr. Carnegie in his Saint Andrews' address assigned to our own iron deposits a life of sixty years, while Professor Shaler in his book — unfortunately his last — on the "Earth and Man," reduces that span to fifty years. Our anthracite is a rapidly vanishing quantity, and vast as are our bituminous coal fields, they will not last forever. And we are using nature's resources with most wasteful prodigality. We are draining our prolific cow to the last drop — skimming off the cream, and not even making cheese out of the skimmed milk. We are saving only 60 per cent. of our anthracite, burning away the by-product of 90 per cent. of all our coke ovens, and cutting down our vast

forests without replanting. In fact, except in the northwest our timber resources are almost exhausted, and we are borrowing largely from Canada. And from abroad we shall sooner or later have to borrow more than timber. When we reach that stage, we will make less money, which will be far from an evil, for it may oblige us to replace some of our pelf with humility and meekness of spirit. Even today we do not suffer acutely from looking abroad for some of the material of our prosperous manufacturers. We do not make any pig tin — on the contrary, import it from the Malay Peninsula, whence we do not refuse to draw it, though it is made by Chinese labor; and yet our tin plate industry is flourishing. And so, as our resources fail, we shall not lack for raw material as long as the world's supply lasts, for transportation charges by land and water will grow steadily less, and we cannot but believe that many of the selfish barriers which now separate nations commercially will be swept away by the spread of saner notions on political economy, and more unselfish international relations.

The extraordinary wealth which has been accumulated of late years, primarily through the marvellous growth of our railroads and the rapid development and utilization of our resources of all kinds, due to that railroad extension, is undoubtedly a menace. But the grave question is how to right the wrong and avert the dangers without retarding the progress; how we can cure the patient without killing him. For if a few of the leaders in the movement have become too rich, their proportion of the gross turnover has been small. Mr. Fisk, in an interesting review of the operations of the Illinois Central in his last annual report, gives the following figures, which are relatively true of all our industries:

"In 1886 of every $100 paid by the Public to the Company there was returned to the Public on or near the line of the Railroad, for operation expenses and taxes $61.71; there were paid for fixed charges $22.83, and there were left for dividends $15.46.

"In 1905, on the other hand, of every $100 paid by the Public to the Company there were returned to the Public on or near the line of the Railroad, for operation expenses and taxes $74.32; there were paid for fixed charges $13.02, and there were left for dividends $12.66. These dividends include revenue from other sources, in 1886 from the sale of lands and from interest on invest-

ments; and in 1905 from dividends and interest on stocks and bonds of this and other companies."

The people at large, therefore, quite apart from the multitude who hold the stock of these great corporations, benefit to the extent of three-quarters of the the gross expenditure. And this is substantially true of all our successful enterprises. Of the statistics of the unsuccessful ventures, in which capital loses a great deal of its money, we hear little. But the operations of the successful ones are on such a stupendous scale nowadays that the comparatively small amount received by those whom we call the promoter per unit of output, whether in the form of material or in the form of energy, represent those great private fortunes which are a stimulant to some, a source of jealousy to others and of wonderment to all. To many of their possessors they are certainly a cause of keen heart searching for some of them certainly find great difficulty in disposing of their accumulation, and we may therefore assume that they feel acutely the responsibility of its possession, and of wisely administering it. To check the growth in future of their fortunes by legislation is the evident, if not the avowed or understood object of much state and federal legislation. If it can succeed in doing so without checking the development of the enterprises which have created these fortunes, no harm will certainly be done, and many of us will thereby be saved from temptation. But probably the evil will remedy itself, for in making haste to be rich every one has been making corresponding haste in depleting our national resources — cropping and recropping our fertile prairie lands, and not restoring their fertility by manure — emptying our mines more rapidly in a decade than old Europe has emptied hers in as many centuries—cutting down our forests, and leaving the refuse lumber a prey to fire, and covering our land with railroads by which these extraordinary results have been brought about. We stand aghast at our own handiwork, and wonder what will be the outcome. The outcome will inevitably be a more modest pace and a saner frame of mind as our resources become gradually exhausted and some men will have to work harder for less pay.

But it will not be the mechanical engineer, or the mining engineer, or the chemist, who will suffer; for as we begin to feel the pinch of want and really appreciate that our resources are not illimitable, and that we must stop wasting and use some economy

we will be obliged to look to you to save us. By-products have been a by-word among us heretofore. Ere long they will be here as elsewhere the salvation of our industries. and you will be the saviours, for to you the nation will look to maintain the supreme position it has secured. She has attained it by the most energetic use of nature's resources. You must do it by the introduction of economies we now almost despise, and by inventing substitutes for material which is now cheap and abundant, but will be ere long scarce and costly. We already see a symptom of the coming change, an unconscious prophecy as it were of future development, in the increasing substitution of concrete, the ingredients of which on the surface of the earth are substantially inexhaustible, for the metals which will soon become rare, and in the generation of heat by the conversion of force instead of exclusively by the combustion of carbon.

You have therefore before you for solution problems of most momentous importance, not only to this country but to the world at large, for thank heaven, selfishness may build tariff walls against trade and folly, or ambition embroil nations in war, but no one has yet been able to confine the divine prerogative of free thought or of free speech by those brave enough to use it, and that I am sure you will be.

NORTH AMERICAN INDEX FOSSILS. II.

By A. W. GRABAU and H. W. SHIMER.*

Phylum IV. MOLLUSCOIDEA.

Class **Bryozoa (Polyzoa.)**

The Bryozoa or Polyzoa are marine or fresh-water animals almost always occurring in colonies, known as *zoaria*, which increase by gemmation. Each *zooid* of the colony is enclosed in a membranaceous or calcareous double-walled sac, the *zoœcium*, into which it can withdraw (Fig. 176*a*). The animal possesses a mouth, an alimentary canal, and an anal opening, and, in addition to these, a fringe of respiratory tentacles —the lophophore (Fig. 176*b*). The colony is commonly attached to foreign bodies, which it either encrusts or from which it arises as an independent frond. The frond may be *unilaminar*, *i e.* with the cells opening on one side only. It may be encrusting or lined with a basal *epitheca*. When the ends of such a unilaminar frond unite, a hollow tube lined with epitheca is produced. Again the frond may be *bilaminar* or *bifoliate*, with the *epithecæ* of the two parts growing together, forming a *mesotheca*. This often contains *median tubuli*. Other forms are *massy* (hemispheric, globular, or discoidal in shape) with gemmation on all sides; *ramose* or branching and *dendroid*.

Fig. 176*a*. *Membranipora pilosa* (recent). Two zooids, one expanded and one withdrawn into the transparent zoœcium. Enlarged. (After Farre.)

A network is often formed, when the branches grow together, leaving *fenestrules* along the border of which are found the apertures of the cells. The branches, instead of anastomosing, may be straight and united at intervals by cross-bars or *dissepiments* which commonly have no apertures (Fenestella, etc.). The branches may be ornamented by nodules, spines or a longitudinal *keel* or *carina*; this latter may be sharp, expand, or even bear a com-

* Copyright 1906.

plicated superstructure. In some types (Archimedes) these fronds are twisted in a spiral form, of which generally the solid axis alone is fully preserved in fossil form.

In the Palæozoic genera the cell apertures are often surrounded by elevated rims or *peristomes*. Often a portion of the posterior wall is more or less thickened and curved to a shorter radius, forming *lunaria*, the ends of which may project into the tube as *pseudosepta*. At the junction of the apertures small cylindrical tubules projecting above as spines, the *acanthopores*, often occur. When the zoœcial tubes are crowded and thin-walled their apertures generally have an angular outline, but when they are thick-walled or separated by interspaces, they are circular, oval or variously formed. The interspaces may be occupied by smaller tubes, the *mesopores*, or by vesicular tissue. The mesopores may be scattered or gathered into clusters. Elevations or *monticules* and flattened or depressed spots or *maculae* are other characteristic surface features. They may be solid or contain the openings of zoœcia (generally somewhat larger than the ordinary) or of mesopores.

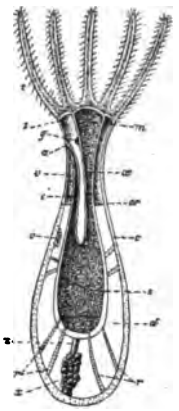

FIG. 176*b*. Diagram showing structure of single bryozoon zooid. (After Busk.) *a*, anus; *c*, ectocyst; *d*, perigastric space; *g*, nerve ganglion; *i*, intestine; *l*, lophophore; *m*, month; *o*, ovary; *oe*, œsophagus; *or*, aperture of the zoœcium; *r*, retractor muscles; *s*, stomach; *t*, tentacles; *v*, tentacular sheath; *x*, testis; *z*, funiculus.

In the Cryptostomata the opening of the zoœcium is the cell orifice. Above this occurs a tubular shaft formed by the thickening of the surface of the zoarium for strengthening or protective purposes. This shaft is the vestibule, and its aperture is variously formed.

In most Palæozoic Bryozoa the tubes are variously divided by cross plates or *diaphragms* which in some types are vesicular, forming *cystiphragms* (Trepostomata). The diaphragms may be complete or pierced by a central opening. In the Cryptostomata additional plates the *hemisepta* project from the wall into the cavity. When they project from the posterior wall, they are known as *superior hemisepta*, when they project from the anterior wall they

are the *inferior hemisepta.* In the Chilostomata the wall is frequently only partly calcified and hence in fossil forms the cell opening is very large. Additional pores the *avicularia* are commonly found.

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ARTIFICIAL KEY TO GENERA.

I. CTENOSTOMATA. — Zoœcia horny or membranaceous, isolated, budding from internodes of tubular stolon; sometimes appearing as excavation in the host... A.

A. Thread-like, or very slightly swollen in center..... *.

* Arrangement net-like or pinnate..... I. *Rhopalonaria.*

* Arrangement more or less radial..... III. *Vinella.*

A. Swollen, bulb or sausage-like ..... **.

** Arrangement in linear series..... IV. *Allonema.*

** Arrangement radial, at intervals along slender stolon..... II. *Ascodictyon.*

II. CYCLOSTOMATA. — Zoœcia simple calcareous tubes, usually without transverse partitions, singly or in association ..... B.

B. Zoœcia free throughout in loosely united branches or strings..... ***.

*** Tubes in linear series, budding one from the other uniserially..... 1.

1. Dichotomously branching, apertures subterminal..... V. *Stomatopora.*

1. Irregular branching, apertures terminal..... X. *Hernodia.*

*** Tubes budding on two or more sides from a linear median stolon ..... 2.

2. Branching; tubes separate and distinct..... IX. *Hederella.*

2. Branching; tubes closely parallel in contact, and of uniform length. XI. *Reptaria.*

B. Zoœcia united wholly or partly in bundles of two or more; no interstitial cells. ****.

**** Zoœcia few in conical bundles of two or more..... ..... 3.
3. Subterminal apertures not elevated ..... XIII. *Phacelopora.*
3. Terminal apertures, elevated at right angles to axis of branch, frequently free..... XCVIII. *Filifascigera.*
**** Zoœcia numerous..... 4.
4. Zoarium a more or less flattened expansion or attached stem..... *a.*
a. Of flattened attached stems sometimes widening or uniting into sheets, tubes slightly or not at all projecting.. VI. *Proboscina.*
a. Spreading fronds, with ends of tubes projecting..... *aa.*
aa. Free, bifoliate ..... VIII. *Diastoporina.*
aa. Attached, tubes on one side only..... .. VII. *Berenicea.*
a. Obconical or cup-shaped, attached by center of sides with epitheca, tubes not projecting..... ..... XCIX. *Discosparsa.*
4. Zoarium a branching cylindrical stem with more or less freely projecting tube ends ..... *b.*
b. Tubes regular, distant, generally much exserted.. XII. *Mitoclema.*
b. Tubes crowded slightly exserted, branches hollow, cavity divided by transverse partitions..... C. *Cavaria.*
B. Zoœcia in compound zoaria, with interstitial cells or mesopores.. ..... 5*.
5* Walls of adjoining zoœcia thoroughly amalgamated and pierced by numerous pores, no lunaria ..... 5.
5. Variously formed generally massy with basal epitheca, and uniform zoœcial apertures ..... CI. *Ceriopora.*
5. Massy or branching, numerous mesopores or interstitial cells between the zoœcia..... CII. *Heteropora.*
5. Of hollow branches the cavity divided by transverse plates; surface with maculæ and mesopores..... C. *Cavaria.*
5* Walls minutely porous, lunarium present, often very prominent, surface with maculæ or monticules..... ..... 6.
6. Encrusting ..... *c.*
c Lamellose expansions.... .... *bb.*
bb. Mesopores abundant..... ..... *11.*
11. Lunarium forming pronounced hood.
XV. *Ceramoporella.*
11. Lunarium not hooded, interspaces with vesicles.
Fistulipora.
bb. Mesopores few .... *22.*
22. Mesopores scattered..... XVIII. *Anolotichia.*
22. Mesopores mostly in maculæ..... XVI. *Crepipora.*
c. Disc-shaped, apertures in radiating ridges.. XXV. *Botryllopora.*
6. Lamellate or massy..... *d.*
d. Mesopores few, decreasing toward margin.... XIV. *Ceramopora.*
d. Mesopores numerous..... *cc.*
cc. Lunarium well raised... ..... XX. *Bythotrypa.*
cc. Lunarium moderate, interspaces with vesicles.
XXI. *Fistulipora.*
cc. Lunarium a strong bidentate process, interspaces with vesicles .... XXIII. *Buskopora.*
6. Branching, more or less cylindrical..... *e.*
e. Branches hollow, lined on inside with epitheca, lunarium hooded.
XVII. *Coeloclema.*

e. Branches hollow, with irregularly expanding and contracting axial tube; diaphragms few or absent, interspaces with vesicles. XXII. *Chilotrypa.*

e. Branches solid; diaphragms present..... XVI. *Crepipora.*

6. Zoarium bifoliate..... *f.*

f. Lunarium prominent, hood-like..... XIX. *Ceramophylla.*

f. Lunarium not prominent, interspaces with vesicles. XXIV. *Meekopora.*

III. TREPOSTOMATA. Zoaria compound, with walls of zoœcia thickened in the outer region with numerous diaphragms or cystiphragms, and monticules or maculæ on surface. Tubes separating upon fracture..... c.

c. Cystiphragms always in outer region, acanthopores mostly abundant..... 6*.

6* Mesopores few or wanting..... 7.

7. Mesopores scattered or absent, acanthopores small and numerous, cystiphragms throughout, walls granulose.. XXVI. *Monticulipora.*

7. Mesopores few, in clusters, acanthopores generally developed, cystiphragms in outer region only ..... XXVIII. *Homotrypa.*

6* Mesopores numerous ..... 8.

8. Apertures irregularly petaloid..... XXVII. *Atactoporella.*

8. Apertures rounded to polygonal..... *g.*

g. Massive conical or discoidal usually free, with wrinkled epitheca on under side..... *dd.*

dd. Zoœcia with cystiphragms..... XXIX. *Prasopora.*

dd. Zoœcia with oblique or funnel-shaped diaphragms (modified cystiphragm)..... XXXI. *Mesotrypa.*

g. Zoarium a thin expansion with epitheca..... XXX. *Aspidopora.*

c. Diaphragms instead of cystiphragms in outer region of zoœcial tubes..... ‡

‡ Mesopores few or absent..... 7*.

7* Acanthopores present..... 9.

9. Acanthopores large..... *h.*

h. Diaphragms of zoœcia few or wanting..... *ee.*

ee. Erect, ramose, diaphragms few... XXXVI. *Dekayia.*

ee. Ramose, slender diaphragms practically absent, acanthopores sometimes wanting.. XXXVIII. *Bythopora.*

h. Diaphragms often numerous ..... *ff.*

ff. Zoœcia with well-marked division line between walls. XXXII. *Amplexopora.*

ff. Zoœcia with periodically thickened walls in mature region..... XL. *Stenopora.*

9. Acanthopores small, few, or wanting..... *i.*

i. Zoœcia with well-marked division line. XXXII. *Amplexopora.*

i. Zoœcia with thick walls..... XXXIX. *Eridotrypa.*

i. Bifoliate with flexuous mesotheca..... XXXIV. *Petalotrypa.*

7* Acanthopores absent..... 10.

10. Zoœcia with well-marked division line.. XXXIII. *Monotrypella.*

10. Zoœcia thick-walled, many diaphragms.. XXXIX. *Eridotrypa.*

‡ Mesopores numerous..... 8*.

8* Zoarium ramose, sometimes with anastomosing branches..... 11.

11. Diaphragms numerous..... *j.*

j. Acanthopores of two sets, large and small. XXXV. *Dekayella.*

j. Acanthopores small, few or wanting.. XXXIX. *Eridotrypa*.
j. Acanthopores large, abundant..... XLIII. *Batostoma*.
j. Acanthopores absent ..... XLVII. *Callopora*.
11. Diaphragms few .... *k*.
k. Mesopores small with subcircular openings.
XXXVII. *Batostomella*.
k. Mesopores irregularly angular, often obscurely moniliform.
XLVI. *Trematopora*.
8* Zoarium erect, flattened fronds or laminar expansions..... 12.
12. Mesopores gathered into maculæ, apertures on elevated stellate rays..... XLI. *Constellaria*.
12. Mesopores numerous, in interzoœcial space, filled and obscured by calcareous tissue in older individuals.. XLII. *Nicholsonella*.
8* Zoarium encrusting foreign bodies, apertures oval, mesopores abundant ..... XLIV. *Stromatotrypa*.
8* Zoarium massive, hemispheric, subglobose or discoidal; neither mesopores nor acanthopores: zoœcial walls often crinkled.
XLV. *Monotrypa*.

IV. CRYPTOSTOMATA. Zoaria compound often highly complex; zoœcia with a short tubular primitive portion, above which, in the "mature" part, is a tubular shaft or vestibule, often with hemisepta, and surrounded by vesicular or solid calcareous tissue; external orifice round..... D.
D. Zoarium a reticulated network or expansion pierced by holes or fenestrules and celluliferous on one side only..... ‡‡.
‡‡ Branches and connecting bars or dissepiments distinct, the latter non-poriferous..... 9*.
9* Apertures on branches in two rows separated by a median keel... 13.
13. Keel moderate, plain, or tuberculated..... *l*.
l. Funnel-shaped structure ..... L. *Fenestella*.
l. Spirally wound axis..... LVII. *Archimedes*.
13. Keel high, expanded at the summit ..... *m*.
m. Expanded portion of keel with large or scattered pores or pits..... LII. *Fenestrapora*.
m. Expanded portion of keel without pores or pits.
LI. *Semicoscinium*.
13. Keel supporting a superstructure..... *n*.
n. Superstructure of thin oblique subimbricating plates (scalæ).
LIII. *Unitrypa*.
n. Superstructure a reticulated network ..... LV. *Hemitrypa*.
9* Apertures in more than two rows (rarely two)..... 14.
14. No median keel (or row of tubercles)..... *o*.
o. Apertures in 2 to 8 rows in a branch, frond as in Fenestella.
LVIII. *Polypora*.
o. Apertures in 2 to 5 ranges; frond supported by non-poriferous U- or V-shaped base ..... LX. *Lyropora*.
14. A prominent median keel present, with two rows of apertures at each side ..... LXI. *Fenestralia*.
‡‡ Connecting bars absent or indistinguishable, branches anastomosing. 10*.
10* Branches irregularly anastomosing ..... 15.
15. Two to eight rows of apertures; reverse side longitudinally striated ..... XLVIII. *Phylloporina*.

15. Apertures in 3 to 7 rows; reverse side not striated.
LVI. *Reteporidra.*

10* Regularly anastomosing, or connected by scarcely recognizable dissepiments..... 16.

16. Apertures in two rows, carinæ expanded sometimes to width of branch..... LIV. *Loculipora.*

16. Apertures in 3 to 7 rows, no median carina. LVI. *Reteporidra.*

D. Zoarium a repeatedly branching frond, the branches rarely united by dissepiments (sometimes wanting)..... ‡‡‡.

‡‡‡ Branches flexuous and irregular..... 11*.

11* Apertures angular..... XLIX. *Drymotrypa.*

11* Apertures rounded..... LIX. *Thamniscus.*

‡‡‡ Branches rigid, parallel and regular, sometimes absent..... 12*.

12* Branches short, free, apertures in two rows with median keel.
LXII. *Pinnatopora.*

12* Branches long, oblique, smaller than stipe, occasionally united by thin dissepiments..... LXIII. *Ptilopora.*

12* Branches wanting..... LXIV. *Diploporaria.*

D. Zoarium of more or less cylindrical branches, preserved generally as fragments. ‡‡‡‡.

‡‡‡‡ Branches in articulating segments or articulated basally..... 13*.

13* Segments with one of several faces longitudinally striated and without apertures..... LXV. *Arthrostylus.*

13* Segments celluliferous on all sides..... 17.

17. Segments uniting by terminal articulation, ends often swollen.
LXVI. *Helopora.*

17. Segments with terminal and lateral (pinnate) articulation, the segments commonly showing the articulating facet on the side.
LXVII. *Arthroclema.*

17. Slender, articulating only at the pointed base, branching above.
LXVIII. *Nematopora.*

‡‡‡‡ Branches not articulating..... 14*.

14* Branch with one side striated and non-celluliferous, the other with two rows of pores..... LXIV. *Diploporaria.*

14* Branches celluliferous on all sides..... 18.

18. Branches solid..... *p.*

p. Apertures in diagonally intersecting series..... *gg.*

gg. Without peristomes..... *33.*

33. Frequently branching..... LXIX. *Rhombopora.*

33. Simple or rarely branching, pointed at base.
LXXI. *Bactropora.*

gg. With peristomes..... *44.*

44. Compressed, dichotomously dividing.
XCVI. *Stictotrypa.*

p. Apertures in longitudinal series..... *hh.*

hh. Cylindrical with pits between apertures.
LXXII. *Streblotrypa.*

hh. Cylindrical without pits..... *Orthopora.*

18. Branches hollow..... *q.*

q. Apertures with depressed vestibules, interspace narrow.
LXX. *Coeloconus.*

q. Apertures small, with elevated generally oblique peristomes.
XCV. *Diamesopora*.

D. Zoarium bifoliate, an explanate frond..... 5‡.
5‡ Mesopores present, frond not articulated..... 15*.
15* Mesopores tabulated..... ..... LXXIX. *Coscinella*.
15* Mesopores not tabulated..... LXXVII. *Stictoporella*.
5‡ Mesopores absent..... ..... 16*.
16* Articulated basally, vestibules separated by thick walls.
LXXV. *Clathropora*.
16* Not articulated, interzoœcial spaces with vesicular tissue.
LXXXVI. *Coscinium*.

D. Zoarium bifoliate ; not explanate..... 6‡.
6‡ Zoarium jointed or articulated at least at the base ..... 17*.
17* Apertures arranged in longitudinal series..... 19.
19. Simple unbranched, lanceolate or falciform frond with basal articulation..... ..... LXXIII. *Ptilodictya*.
19. Bushy, of numerous articulating equal segments spread in a plane..... LXXVI. *Arthropora*.
19. Segments from cylindrical root, two buds from truncated end of preceding..... LXXXVII. *Acrogenia*.
17* Apertures in decussating series surrounded by sloping hexagonal areas..... LXXIV. *Escharopora*.
6‡ Zoarium not articulated..... 18*.
18* Mesopores present..... 20.
20. Mesopores tabulated..... *r*.
r. Zoarium ramose, compressed, divided dichotomously.
LXXVIII. *Intrapora*.
20. Mesopores untabulated ..... LXXVII. *Stictoporella*.
18* Mesopores absent ..... 21.
21. Branches bifurcating, straight edged with parallel or subparallel margins..... ..... *s*.
s. With well marked lunarium, nearest to the margin.
LXXXIII. *Cystodictya*.
s. Without lunarium..... LXXX. *Rhinidictya*.
s. Without lunarium, with maculæ.... LXXXII. *Pachydictya*.
s. With strong central ridge making section somewhat rhombic.
LXXXV. *Taeniopora*.
21. Branches and irregular explanate frond..... *t*.
t. Apertures subelliptical; thin bifoliate expansions, surface with solid maculæ..... LXXXIV. *Dichotrypa*.
t. Apertures semi-elliptical, with broad triangular space beneath each aperture..... XCIII. *Worthenopora*.
t. Apertures with eight to ten vertical septa-like ridges.
XCII. *Actinotrypa*.
t. Apertures oblique, with posterior edge lip-like.
LXXXI. *Phyllodictya*.

D. Zoarium of prismatic branches triangular in cross-section..... 7‡.
7‡ Branches triangular, with faces crossed by transverse ridges.
LXXXIX. *Scalaripora*.
7‡ Faces of triangular branches without transverse ridges.
LXXXVIII. *Prismopora*.

D. Zoarium not belonging to the foregoing..... 8‡.
8‡ Zoarium a thin expansion, traversed on both sides by salient ridges or crests united into cups..... XC. *Glyptopora.*
8‡ Zoarium free, of four or more vertical leaves radially arranged. XCI. *Evactinopora.*
8‡ Zoarium a subcircular unilaminar expansion with basal epitheca. XCIV. *Lichenalia.*
8‡ Zoarium a thin incrustation, with hexagonal or polygonal apertures. XCVII. *Paleschara.*

V. CHILOSTOMATA. Zoœcia of various forms arranged side by side with more or less anterior orifice of smaller diameter than zoœcium and closed by a movable cover, appearing often to occupy the whole surface of zoarium owing to non-calcification of the front wall and its removal in fossilization.....E.
E. Bifoliate, mostly free..... 9‡.
9‡ Apertures in longitudinal series, oval, and occupying most of the cell surface..... CIII. *Biflustra.*
9‡ Apertures semilunar or crescentic in a large hexagonal area. CIV. *Onychocella.*
E. Cells on one side only..... 10‡.
10‡ Cells with openings occupying the whole or nearly the whole of the exposed surface; encrusting..... CV. *Membranipora.*
10‡ Cells with opening only in anterior part; form bulbous or urn-shaped. 19*.
19* Aperture entire, with one or more supplementary pores. CVI. *Adeoneliopsis.*
19* Apertures notched below, supplemental pores not present. CVII. *Schizoporella.*

PALÆOZOIC SPECIES.

ORDER CTENOSTOMATA Busk.

I. RHOPALONARIA Ulrich.

Zoarium sunken for about half its mass into the object on which it grows (generally a coral, crinoid stem, or shell) and usually preserved only as threadlike excavations in the surface of this object, often filled with clay. Zoœcia unknown. Ordovicic–Mississippian.

1. **R. venosa** Ulrich. (Fig. 177, *a.*) Ordovicic.

Consists of delicate fusiform cells connected by slender stolons of the average length of the cells; branching irregular, pinnate or sometimes netlike. Fusiform cells average 0.3 mm. in length by 0.1 mm. or less in diameter. Excavated in corals, shells, etc. Richmond beds of Ohio and Indiana.

2. **R. attenuata** U. and B. Siluric.

Fusiform cells shorter and farther apart than in preceding. Niagaran beds of New York and Pennsylvania.

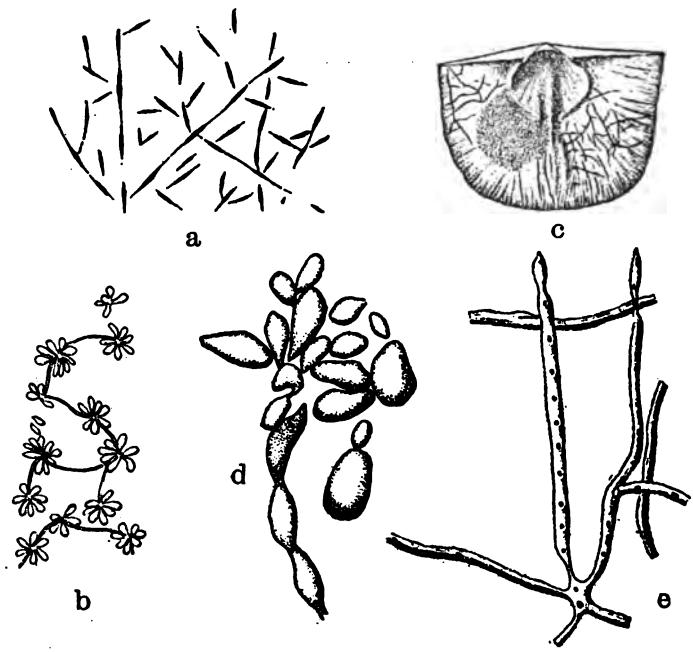


FIG. 177. *a*, *Rhopalonaria venosa* × 9; *b*, *Ascodictyon floreale* × 9; *c*, *Vinella repens* × 1; *d*, *Allonema fusiforme* × 9; *e*, *Vinella repens* × 18. (After Ulrich, and Ulrich and Bassler.)

3. **R. tenuis** U. and B. Devonic.

Like *R. venosus*, but fusiform cells narrower and longer, and connecting stolons shorter.

Hamilton beds of Western New York, Canada and Michigan.

II. ASCODICTYON Nicholson and Etheridge.

Attached to shells, etc., and consisting of ovate or pear-shaped vesicles in clusters or single, arranged along delicate hollow threads or stolons. Zoœcia unknown. Sil.–Miss.

4. **A. stellatum** N. and E. Mid-Ordovicic.

Ovoid or pear-shaped calcareous vesicles, generally in clusters of six or more (sometimes fewer) cells, averaging nearly 1 mm. in diameter, and connected by filamentous tubes.

Hamilton beds of Western New York and Ontario.

5. **A. floreale** U. and B. (Fig. 177, *b*.) Mid-Devonic.

About half the size of the preceding.

Hamilton of Michigan.

III. VINELLA Ulrich.

Attached to shells, crinoid stems, etc., and consisting of very slender tubular stolons arranged in more or less distinct radial manner, each marked in perfect specimens by a single row of pores. Zoœcia unknown.

6. **V. repens** Ulrich. (Fig. 177, *c*, *e*.) Ordovicic.
Radial arrangement imperfect. Stolons often bifurcating.
Black River formation of Minnesota.

IV. ALLONEMA U. and B.

Attached, in form sausage-like strings of vesicles with minute punctate surfaces and a large pore toward one end. Sil.–Penn.?

7. **A. fusiforme** (Nich. and Eth.). (Fig. 177, *d*.) Mid-Devonic.
Fusiform, sometimes ovate cells, isolated or joining one another.
Hamilton of Ontario, Michigan and the Falls of the Ohio.

ORDER CYCLOSTOMATA Busk.

V. STOMATOPORA Brown.

Dichotomously branching colonies of attached subtubular or subpyriform zoœcia, arranged typically in a linear series; apertures subterminal. Ord.–Dev.; Jur.–Recent.

8. **S. inflata** Hall. (Fig. 178, *a*.) Ordovicic.
Pear-shaped cells often forming crowded clusters.
Trenton and Cincinnati beds of New York, Canada, Minnesota, etc., and in the Cincinnati dome region.

9. **S. delicatula** (James). (Fig. 178, *b*.) Ordovicic.
Cells longer and more slender than preceding.
Stones River to Richmond beds of Ohio, Indiana, Kentucky, Tennessee, Illinois, Iowa and Minnesota.

VI. PROBOSCINA Audouin.

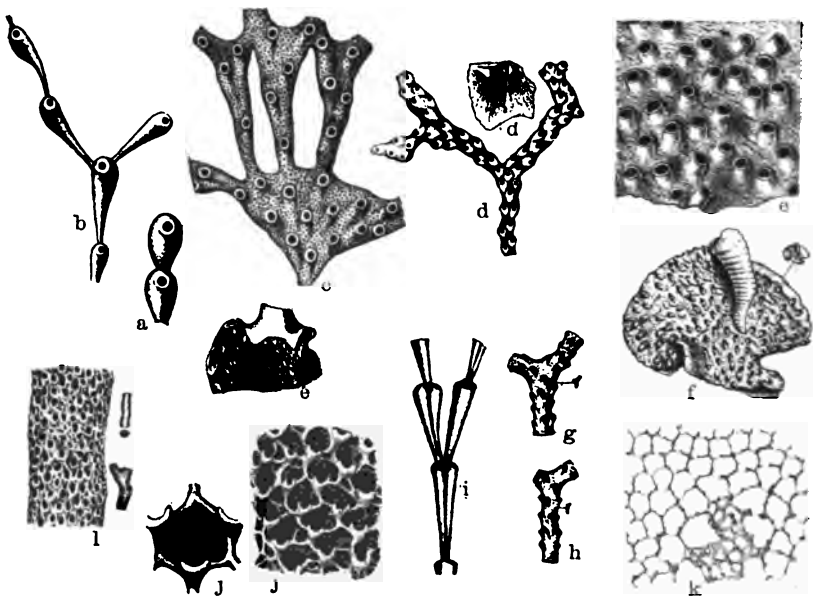
Adhering, of several fused rows of cells, sometimes a sheet-like expansion. Zoœcia tubular with subterminal apertures. Ord.–Dev.?; Jur.–Recent.

10. **P. frondosa** Nicholson. (Fig. 178, *c*.) Ordovicic.
Branches reuniting, with distant zoœcial apertures slightly elevated.
Lorraine and Richmond beds of Ohio, Indiana, Kentucky, Illinois and Manitoba.

11. **P. tumulosa** Ulrich. (Fig. 178, *d.*) Ordovicic.

Narrow bifurcating branches, with a double (rarely triple) row of bulbous zoœcial swellings with apertures.

Black River of Minnesota.



F.G. 178. *a*, *Stomatopora inflata* × 9; *b*, *S. delicatula* × 12½; *c*, *Proboscina frondo a* × 9; *d*, *P. tumulosa* × ½, and × 4½; *e*, *Berenicea minnesotensis* × ½ and × 9; *f*, *Diastoporina flabellata* × ½ and × 3½, with annelid tube attached; *g*, *h*, *Mitoclema mundulum* × ½ and × 4½; *i*, *Phacelopora pertenuis*, × 12½; *j*, *Ceramoporella inclusa* × 9, and × 20; *k*, *Crepipora simulans*, tangential section showing a macula and lunaria × 9; *l*, *Cœloclema trentonense* × ½ and × 4½. (All after Ulrich.)

VII. Berenicea Lamouroux.

Thin, discoid, flabellate or irregular incrustations with tubular zoœcia arranged in irregular, attenuating lines. Ord.–Silur.; Jur.–Recent.

12. **B. minnesotensis** Ulrich. (Fig. 178, *e.*) Ordovicic.

Zoœcia similar to *P. tumulosa*, arranged in irregular rows on a flabellate surface.

Stones River and Black River of Minnesota.

VIII. Diastoporina Ulrich.

Bifoliate zoaria with tubular zoœcia prostrate and partly sunken into the connecting mass. Ordovicic.

13. **D. flabellata** Ulrich. (Fig. 178, *f.*) Ordovicic.

Flabellate or fan-shaped expansion, minute with distant, tubular cells projecting obliquely.

Trenton of Minnesota.

IX. Hederella Hall.

Adhering zoaria with the tubular cells given off on alternate sides from central tubular axis. Devonic.

14. **H. canadensis** (Nicholson). (Fig. 179, *a*, *b*.) Devonic.

Profusely branching, with long, slender zoœcial tubes with oval apertures.

Hamilton group of New York, Ontario, Falls of the Ohio and Upper Canada; Onondaga of Ontario.

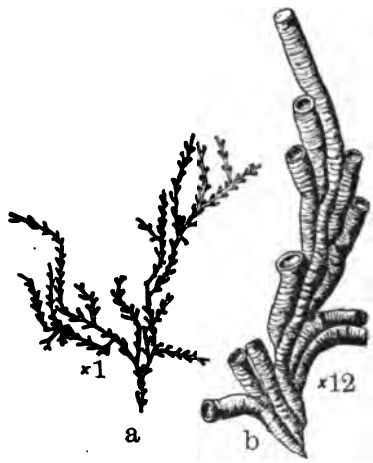


Fig. 179. *Hederella canadense*, *a* × 1, *b* × 12. (After Hall and Simpson.)

X. Hernodia Hall.

Similar to preceding, but later zoœcia budding from preceding ones. Devonic.

15. **H. humifusa** Hall. Devonic.

Cells 5 mm. long, gradually enlarging to aperture, which is about 1 mm. in diameter, budding about one third the distance below the aperture.

Hamilton of New York and Falls of the Ohio.

XI. Reptaria Rolle.

Like *Hederella*, but zoœcial tubes parallel and closely placed. Devonic.

16. **R. stolonifera** Rolle. (Fig. 180, *a*, *b*.) Devonic.

Tubes of equal length, slightly annulated, with the last cell terminal.

Hamilton of Western New York.

XII. Mitoclema Ulrich.

Minute, cylindrical, branching stems with zoœcia bending abruptly outwards and often projecting free. Ordovicic.

17. **M. mundulum** Ulrich. (Fig. 178, *g*, *h*.) Ordovicic.

Branches about half a millimeter in diameter, faintly striated transversely, and with the tube-like zoœcia projecting upward and outward in a spiral series.

Trenton of Minnesota.

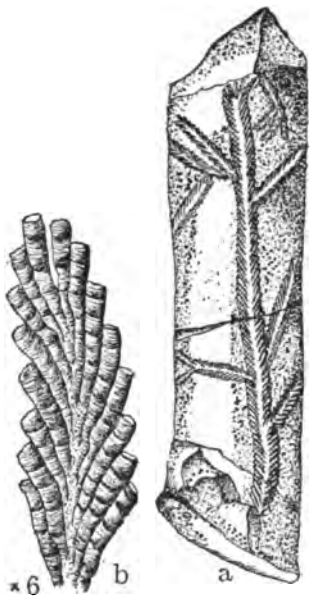


FIG. 180. *Reptaria stolonifera*: *a*, frond on Orthoceras × 1; *b*, portion enlarged × 6. (After Hall and Simpson.)

XIII. PHACELOPORA Ulrich.

Zoarium articulated; two or more conical zoœcia form cone-shaped bundles, with circular slightly contracted subterminal aperture. Ord.–Sil.

18. **P. pertenuis** Ulrich. (Fig. 178, *i*.) Ordovicic.

Minute, thread-like, the segments in linear series, frequently double, producing a dichotomous branching, and each comprising a pair of zoœcia, 0.6 to 0.8 mm. in length.

Richmond of Illinois.

XIV. CERAMOPORA Hall.

Discoidal zoaria free or attached by center of base; under surface with one or more layers of small irregular cells; zoœcia radiating from depressed center on upper surface, with oblique apertures imbricating, and short, irregular mesopores decreasing in number outward. Siluric.

19. **C. imbricata** Hall. (Fig. 181.) Siluric.

Depressed hemispheric, flattened or convex on lower side; apertures arched or triangular, opening on all sides toward outer margin, in alternate imbricating series.

Niagara of New York, Indiana, etc.

XV. CERAMOPORELLA Ulrich.

Zoarium of incrusting layers, often on other Bryozoa, with short, tubular, thin-walled zoœcia with oval oblique apertures, the lunarium forming a hood; abundant mesopores. Ordovicic.

20. **C. inclusa** Ulrich. (Fig. 178, *j*.) Ordovicic.

Thin incrustations with the oval zoœcial apertures occupying, each with three mesopores, the bottoms of subtriangular or rhomboidal obliquely depressed spaces; lunarium strongly elevated.

Stones River, Black River, and Trenton, of Minnesota.

21. **C. distincta** Ulrich. Ordovicic.

Apertures oblique, with overhanging hood, radially arranged about small maculæ and separated by a linear series of mesopores.

FIG. 181. *Ceramopora imbricata* with enlargement of surface.

Utica and Lorraine of Cincinnati region.

22. **C. ohioensis** (Nicholson). Ordovicic.

Cells in intersecting diagonal lines disposed around elevated clusters of larger zoœcia; few mesopores.

Common in the Utica, Lorraine, and Richmond groups of Ohio, Indiana, Kentucky, Tennessee, Illinois and Wisconsin.

XVI. CREPIPORA Ulrich.

Incrusting, lamellate massive, or hollow branches with long, tubular, thin-walled zoœcia, bearing diaphragms, and having angular or subpyriform apertures, the lunarium not overarching, its ends usually projecting; mesopores on elevated or depressed maculæ. Ordovicic.

23. **C. simulans** Ulrich. (Fig. 178, *k*.) Ordovicic.

Clusters of mesopores at ntervals of three or four millimeters, with the zoœcial apertures surrounding concentrically and larger near the clusters; lunarium not prominent.

Trenton of Kentucky and Tennessee; Lorraine of Ohio, Indiana, Kentucky and Tennessee; Richmond, of Ohio, Indiana, Illinois, Wisconsin and Kentucky.

XVII. COELOCLEMA Ulrich.

Hollow branches lined internally with striated epithecæ; zoœcia as in *Ceramoporella*, but with thicker walls. Ordovicic.

24. **C. trentonense** (Ulrich). (Fig. 178, *l*.) Ordovicic.

Small apertures in depressed areas, with lunarium not prominent, and two or three mesopores to each zoœcium, regularly or irregularly arranged.

Trenton of New York, Canada and Minnesota.

XVIII. Anolotichia Ulrich.

Ramose or digitate zoaria of subpolygonal tubes with remote diaphragms, lunarium elevated at surface, traversed by fine vertical tabulated tubes. Mesopores few. Ordovicic.

25. **A. impolita** (Ulrich). (Fig. 182, *a*.) Ordovicic.

Large, bushy, of frequently and irregularly divided solid branches; large, moderately thin-walled zoœcia, with hexagonal, subrhomboidal apertures, practically of uniform size and with well-developed lunarium.

Stones River of Minnesota; abundant and characteristic.

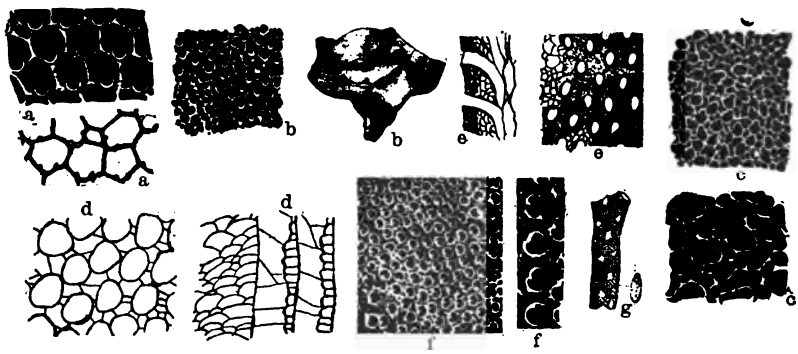


Fig. 182. *a*, *Anolotichia impolita*, surface and section, × 9; *b*, *Ceramophylla frondosa*, × ½ and surface, × 4½; *c*, *Bythotrypa laxata*, surface, × 4½ and × 9; *d*, *Fistulipora carbonaria*, tangential and longitudinal sections, × 9; *e*, *Chilotrypa hispida*, half of a vertical section with axial tube on right, and tangential section showing interstitial vesicles, × 9; *f*, *Buskopora dentuta*, surface × 4½ and × 9; *g*, *Meekopora clausa* and section, × ½. (All after Ulrich.)

XIX. Ceramophylla Ulrich.

Like *Ceramoporella*, but erect and bifoliate, the two layers grown back to back. Ordovicic.

26. **C. frondosa** Ulrich. (Fig. 182, *b*.) Ordovicic.

Fronds 0.5 to 2.0 mm. in thickness; substellate maculæ of mesopores at intervals of about 3 mm.; oblique apertures with posterior margin well elevated, and 2 to 3 mesopores to each zoœcium.

Black River of Minnesota.

XX. Bythotrypa Ulrich.

Massy or lamellate, with long zoœcial tubes with thin diaphragms, subovate apertures and large lunaria. Numerous meso-

pores open to the surface and form internally a loose vesicular tissue. Ordovicic.

27. **B. laxata** Ulrich. (Fig. 182, *c*.) Ordovicic.

Massy, originally attached, with basal epitheca; subovate apertures with broad, sharply elevated lunarium; numerous mesopores which at intervals form clusters (in weathered specimens) from which zoœcia radiate. Interior irregularly and loosely arranged; walls of granular structure.

Stones River to Trenton of Minnesota, Iowa and Illinois.

XXI. Fistulipora McCoy.

Form various, the under surface with wrinkled epitheca; cylindrical or somewhat compressed zoœcial tubes with few diaphragms,

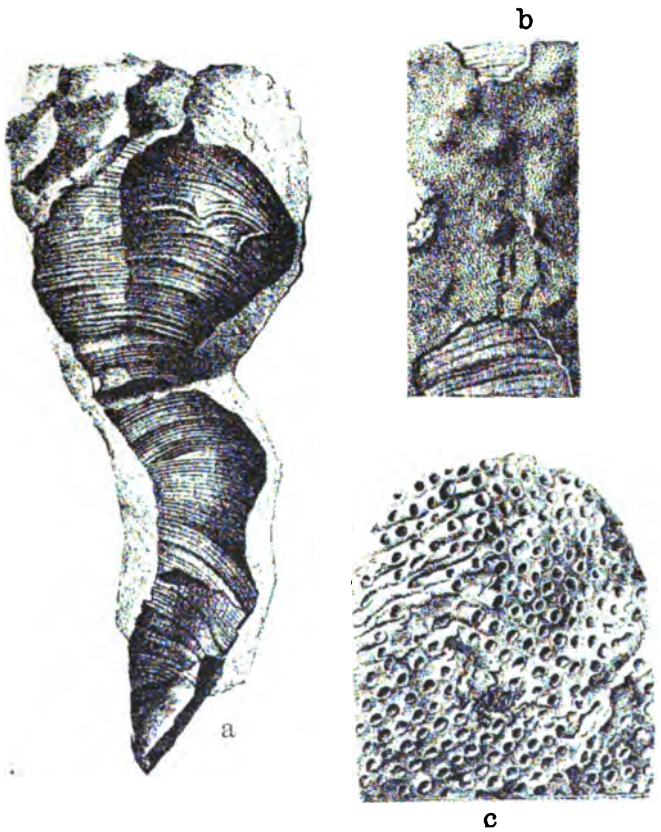


Fig. 183. *Fistulipora torta; a*, epithecal side, × 1; *b*, celluliferous side, × 1; *c*, enlargement of part of *b*. (After Hall.)

surrounded by vesicles; apertures subradially arranged about the maculæ, with more or less strongly developed lunarium, and separated by smooth or granular interspaces. Siluric to Carbonic.

28. **F. neglecta** Rominger. Siluric.

Irregular expansion; base with concentrically wrinkled epitheca; surface with irregularly scattered, smooth maculæ, from which the circular to oval oblique apertures radiate irregularly. Generally adheres by celluliferous face. (Generally identified as *Lichenalia concentrica.*)

Niagara of Indiana, Kentucky, etc.

29. **F. torta** (Hall). (*Lichenalia torta* Hall). (Fig. 183, *a–c.*) Lower Devonic.

Lamellate expansions, flat or involved and contorted, epitheca finely striated radially on under side, and sharply on upper (when cells are removed), nodose at junction, with concentric striæ; apertures circular or oval to trilobate, posterior margin strongly elevated and separated by interspaces of equal size with the apertures.

Helderbergian (Coeymans) of New York, etc.

30. **F. carbonaria** Ulrich. (Fig. 182, *d.*) Carbonic.

Irregularly lamellate or submassy, diameter several inches, thickness half an inch or a little more. Apertures oval or circular, with thin, inconspicuous peristome, with a single row of angular mesopores which at intervals form substellate maculæ.

Upper Coal Measures of Missouri, Kansas, etc.

XXII. Chilotrypa Ulrich.

Small, ramose, with narrow, irregularly contracting and expanding axial tube; oblique elliptical apertures, the lower margin thick and elevated; diaphragms few or none. Sil.–Miss.

31. **C. hispida** Ulrich. (Fig. 182, *e.*) Mississippian.

Zoœcia in regular obliquely intersecting series, 8 or 9 in the space of an inch; small maculæ, surrounded by somewhat larger cells; lip decreasing from posterior end forward; interspaces dense above, vesicular lower down.

Chester of Illinois and Kentucky.

32. **C. ostiolata** (Hall). (Fig. 184, *a*, 184, *b.*) Siluric.

Irregularly branching cylindric stems, gradually tapering toward the extremities, which are obtuse; apertures about their extremity

apart, arranged in spirally ascending lines or irregularly; strong peristomes; interapertural spaces smooth; stems solid or encrusting crinoids.

Rochester shales of New York and Ontario.

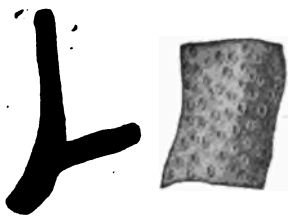


FIG. 184, *a*. *Chilotrypa ostiolata*, branch natural size and enlargement.

FIG. 184, *b*. *Chilotrypa ostiolata*; enlarged.

XXIII. BUSKOPORA Ulrich.

Like Fistulipora, but with pronounced lunarium projecting as bidenticulate process nearly half across aperture. Devonic.

33. **B. dentata** Ulrich. (Fig. 182, *f*.) Devonic.

Incrusting or free expansions, with concentrically wrinkled epitheca on lower side; apertures in regular diagonally intersecting lines; slightly elevated maculæ with smooth centers, at intervals of 5 mm.

Hamilton of Falls of the Ohio.

XXIV. MEEKOPORA Ulrich.

Bifoliate (two layers growing back to back), zoœcial tubes gently curving outward, opening obliquely, distally pointed, and with numerous diaphragms. Convex elevations or ovicells with small apical opening occur at intervals. Silur.–Carb.

34. **M. clausa** (Ulrich). (Fig. 182, *g*.) Carbonic.

Compressed branches, surface with substellate maculæ, between which the zoœcia are uniformly distributed in very regular oblique series; interapertural space flat or slightly concave, usually smooth or minutely pitted or granular, vesiculose in lower part.

Chester of Illinois and Kentucky.

XXV. Botryllopora Nicholson.

Disk-shaped, often coalescing, attached bodies, the apertures in two rows on elevated radiating ridges, increasing by bifurcation or implantation towards margin. No lunaria. Devonic.

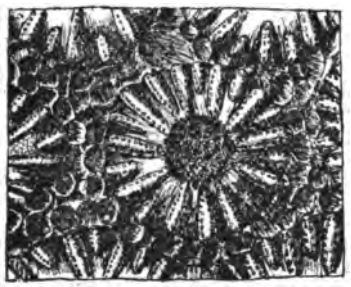


Fig. 185. *Botryllopora socialis*, portion of a colony much enlarged. (After Hall and Simpson.)

35. **B. socialis** Nicholson. (Fig. 185.) Devonic.

Alternate ridges extend to the central area, others one-half to two-thirds that distance; apertures minute, often in contact or inosculating.

Hamilton of Western New York, Ontario, Michigan, and the Falls of the Ohio.

Order TREPOSTOMATA Ulrich.

XXVI. Monticulipora d'Orbigny.

Form various, of prismatic zoœcia with cystiphragms and polygonal apertures; monticules and acanthopores occur; mesopores few or wanting; zoœcial apertures polygonal; cystiphragms in mature region. Ord.–?Dev.

36. **M. mammulata** d' Orb. Ordovicic.

Irregularly lobate or palmate, with prominent conical or sometimes elongated monticules; cells of monticules of about same size as others.

Lorraine of the Cincinnati region and Kentucky.

37. **M. arborea** Ulrich. (Fig. 186, *a*.) Ordovicic.

Subcylindrical branches, monticules low or absent, apertures with minutely granular walls bearing acanthopores. No mesopores.

Trenton of Minnesota, Iowa, and Kentucky.

XXVII. Atactoporella Ulrich.

Generally encrusting; apertures petaloid, mesopores numerous, frequently isolating the zoœcia; acanthopores very numerous. Ordovicic.

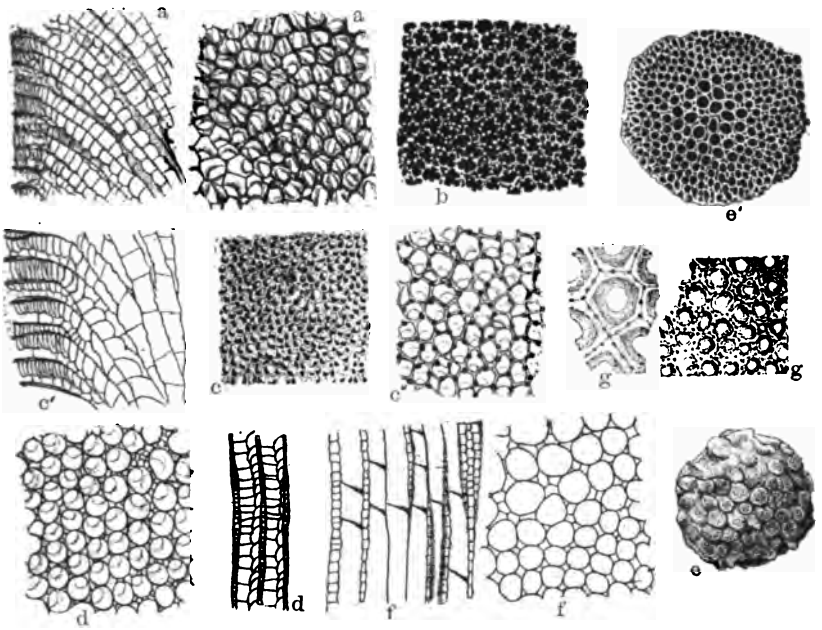


FIG. 186. *a*, *Monticulipora arborea*, peripheral part of vertical sect. and tangential sect. × 9; *b*, *Atactoporella typicalis* var. *praecipta*, surface × 9; *c*, *Homotrypa subramosa*, surface × 4½, *c''* × 9 and *c'* half of vertical sect. × 9; *d*, *Prasopora simulatrix*, tangential and vertical sections × 9; *e*, *Aspidopora elegantula*, entire head × ½; *e'*, part of surface × 4½; *f*, *Mesotrypa quebecensis*, vertical and tangential sections × 9, *g*, *Amplexopora cingulata*, tangential sections × 9 and × 20. (All after Ulrich.)

38. **A. typicalis** Ulrich. (Fig. 186, *b*.) Ordovicic.

Thin crusts on other bryozoans, groups of larger cells at unequal intervals, sometimes on monticules; cells very regular.

Utica of Kentucky and Ohio. A closely related variety (var. præcipta Ulrich) occurs in the Black River of Minnesota.

XXVIII. HOMOTRYPA Ulrich.

Frondescent or ramose, the surface showing monticules or maculæ of larger cells; zoœcia with very thin or finely crenulated walls, remote diaphragms in immature and cystiphragms in mature region, and apertures often oblique. Mesopores and acanthopores present, the former few and in clusters. Ord.–Sil.

39. **H. subramosa** Ulrich. (Fig. 186, *c*.) Ordovicic.

Irregularly branching; monticules low and ill-defined; axial region tabulated.

Black River of Minnesota.

40. **H. obliqua** Ulrich. Ordovicic.

Flattened branches with well-developed monticules as in *Monticulipora*, from which it is readily distinguished by the larger cells of the monticules.

Lorraine of Cincinnati region.

41. **H. curvata** Ulrich. Ordovicic.

Differs from preceding in absence of monticules, and occurrence of stellar maculæ of minute cells, but appearing smooth, and surrounded by larger cells than average.

Lorraine of the Cincinnati region.

42. **H. flabellaris** Ulrich. Ordovicic.

Growth fan-shaped, surface with obscure maculæ with centers about 4 mm. apart; walls of tubes very thin, appearing flexuous or crenulated in section, with few remote diaphragms in zoœcia, but many in mesopores.

Lorraine and Richmond of Illinois, Ohio, Indiana, Kentucky and Tennessee. Common.

43. **H. minnesotensis** Ulrich. Ordovicic.

Subcylindrical branches from 5 to 15 mm. in diameter, generally dividing dichotomously; clusters of larger cells conspicuous in one variety, raised on monticules, about 25 mm. between centers; true mesopores wanting, acanthopores exceedingly small and few; apertures oblique.

Stones River and Black River of Minnesota, Iowa, Kentucky. and Tennessee.

XXIX. Prasopora Nicholson and Etheridge.

Massy, usually free, with wrinkled epitheca on under side; zoœcia prismatic or cylindrical, thin-walled, with cystiphragms, and generally surrounded by angular mesopores with crowded diaphragms; acanthopores rarely numerous or strong. Ordovicic.

44. **P. simulatrix** Ulrich. (Fig. 186, *d*.) Ordovicic.

Discoidal to hemispheric or subconic, base concave; clusters of larger cells with more numerous mesopores at intervals of about 4 mm., sometimes on monticules; an average of 11 cells in 3 mm.

Black River and Trenton of Kentucky, Tennessee, Wisconsin, and Minnesota.

45. **P. lycoperdon** (Hall). Ordovicic.

Differs from preceding in absence of monticules and in large irregular clusters of closely tabulated mesopores, an average of 9 cells in 3 mm., both cells and mesopores being somewhat larger than in preceding species. (The original description is applicable to so many species, which have gone by this name, that many authors have discarded it altogether.)

Trenton of New York, Canada, etc.

XXX. Aspidopora Ulrich.

Zoarium expanded or of superimposed layers, with a basal epitheca; zoœcia decreasing in size outward from center, without diaphragms and few cystiphragms; mesopores numerous, with close diaphragms; acanthopores small or absent. Differs from the preceding mainly in small size and thinness of expansion.

46. **A. elegantula** (Ulrich). (Fig. 186, *e.*) Ordovicic.

Surface with large clusters of large cells at intervals of 3 or 4 mm., generally elevated; mesopores between all zœcia; cystiphragms practically or quite wanting.

Trenton of Minnesota.

47. **A. newberryi** (Nicholson). Ordovicic.

Differs from preceding in absence of elevations and in greater abundance of cystiphragms, which occur in each zoœcium.

Utica beds of the Cincinnati region.

XXXI. Mesotrypa Ulrich.

Like *Prasopora*, but flatter, and with oblique or funnel-shaped diaphragms, and zoœcia separated by angular mesopores with numerous diaphragms; acanthopores sometimes large. Ord.-Sil.

48. **M. quebecensis** (Ami). (Fig. 186, *f.*) Ordovicic.

Varying in height from 4 to 20 mm., and in diameter from 12 to 45 mm. Normal zoœcia 11 or 12 in 3 mm., those of the clusters 0.4 to 0.45 mm. in diameter; oblique diaphragms in zones; acanthopores wanting.

Trenton of Quebec, Vermont, New York, Kentucky and Iowa.

XXXII. Amplexopora Ulrich.

Ramose, discoidal or massy, with prismatic zoœcia with diaphragms; acanthopores variable. Ordovicic.

49. **A. cingulata** Ulrich. (Fig. 186, *g*.) Ordovicic.

Ramose, of cylindrical or subcylindrical branches dividing dichotomously; no monticules; apertures subpolygonal, a moderately thin wall studded with granules between them; groups of cells of larger size; no mesopores.

Lorraine of Kentucky and the Cincinnati, O., region.

XXXIII. Monotrypella Ulrich.

Like *Amplexopora*, but distinguished by the absence of acanthopores. Ord.–Dev.

50. **M.** (**Rhombotrypa**) **quadrata** (Rominger). Ordovicic.

Irregularly cylindrical branches, from 4.5 to 10.5 mm. thick, the tubes rhombic in section, arranged in curved diagonal lines. No mesopores or monticules.

Richmond beds of Ohio, Indiana, Illinois, Wisconsin and Manitoba. Common and characteristic.

51. **M.? arbuscula** (Hall). (Fig. 187.) Siluric.

Fruticose, several slender (2–3 mm.) stems from a single base; bifurcation frequent; cell tubes very gradually diverging to surface.

A characteristic fossil of the Manlius limestone of New York.

Fig. 187. *Monotrypella ? arbuscula.*

XXXIV. Petalotrypa Ulrich.

Irregular, compressed, bifoliate branches or fronds, with prismatic zoœcia arising from strongly flexuous mesotheca with polygonal apertures. Devonic.

52. **P. compressa** Ulrich. (Fig. 190, *a*.) Devonic.

Smooth, with scarcely appreciable clusters of slightly larger and somewhat more separated cells; zoœcia subpolygonal to hexa-

gonal; mesopores irregular, scattered, sometimes in clusters; height 2 mm. or more; width 1 cm. or less; thickness 1 to 4 mm.

Hamilton of Iowa and Illinois.

XXXV. DEKAYELLA Ulrich.

Ramose, zoœcia with numerous diaphragms, large and small acanthopores, and a variable number of mesopores. Ordovicic.

53. **D. praenuntia** Ulrich. (Figs. 188, *b*, 190, *b*.) Ordovicic.

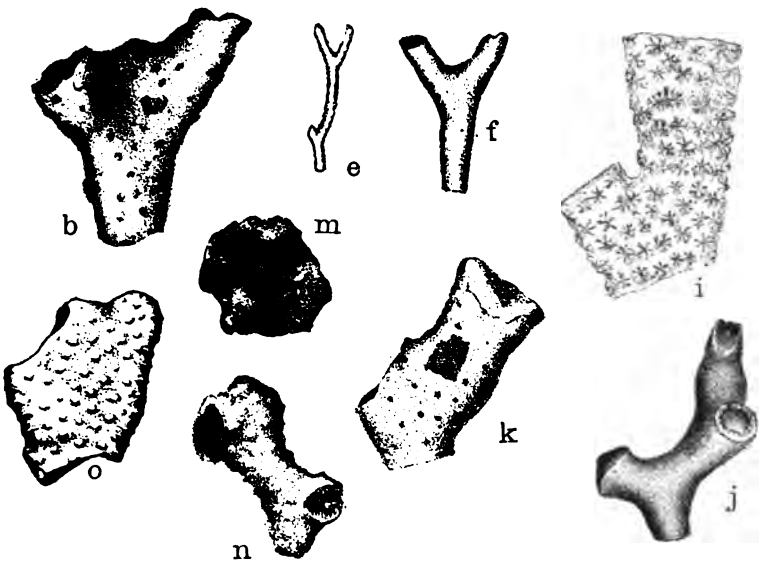


FIG. 188. *b, Dekayella prænuntia* var. *echinata; e, Bythopora herricki; f, Eridotrypa mutabilis; i, Constellaria florida; j, Batostoma winchelli; k, B. fertile; m, Stromatotrypa ovata; n, Callopora multitabulata; o, Nichoisonella pulchra*, broad form. All natural size. For further illustrations see Fig. 190, corresponding letters. (All after Ulrich.)

Compressed cylindrical, from 4 to 12 mm. in diameter; no monticules, but inconspicuous clusters of large cells; few, irregularly disposed mesopores and acanthopores.

Black River of Minnesota.

54. **D. obscura** Ulrich. Ordovicic.

Small, slender stems, variously branching; monticules obscure.

Utica of the Cincinnati region.

55. **D. ulrichi** (Nicholson). Ordovicic.

Coarse, subcylindrical branching stems, three or more times the diameter of preceding; low monticules of smaller cells (meso-

pores) regularly disposed, and surrounded by cells somewhat above the average in size.

Utica beds of the Cincinnati region. A common fossil.

XXXVI. Dekayia E. and H.

Subcylindrical or flattened stems growing from large base; one set of acanthopores and few or no mesopores and diaphragms. Otherwise like preceding. Ord.–?Dev.

56. **D. aspera** E. and H. (Fig. 190, *c.*) Ordovicic.

General form and aspect like *Dekayella ulrichi*, from which it differs in generic characters.

Lorraine of the Cincinnati region.

XXXVII. Batostomella Ulrich.

Slender branches, with thick-walled zœcia, few diaphragms, and small circular or oval apertures with rounded or canaliculate interspaces; numerous small acanthopores, and mesopores, the latter with subcircular openings.

57. **B. granulifera** (Hall). Siluric.

Oval to elongate apertures margined by wavy, raised, granulose lines, double between cells.

Rochester shale of New York, etc.; common. Waldron, Ind.

58. **B. spinulosa** (Ulrich). (Fig. 190, *d.*) Mississippian.

Subcircular or oval apertures, surface hirsute in well preserved specimens, from abundance of acanthopores.

Chester of Kentucky and Illinois.

XXXVIII. Bythopora Miller and Dyer.

Usually slender branches, zoœcia practically without diaphragms, and with oblique apertures, canaliculate interspaces, few mesopores and comparatively strong acanthopores, rarely more than one to each zoœcium. Ord.–Dev.

59. **B. delicatula** (Nicholson). Ordovicic.

Like the preceding, but without the spines.

Richmond beds of Ohio, Indiana, Ontario and Manitoba.

60. **B. herricki** Ulrich. (Figs. 188, *e*, 190, *e.*) Ordovicic.

Similar to preceding, but with apertures long drawn out anteriorly and narrower.

Black River of Minnesota.

61. **B. spinulosa** (Hall). (Fig. 189.) Siluric

Oval apertures on cylindrical branches with strong spines at regular intervals.

Rochester shales of New York, etc.

XXXIX. Eridotrypa Ulrich.

Of slender branches with more or less oblique thick-walled zoœcia with diaphragms which may be absent in the axial and apertural regions. Mesopores with close-set diaphragms, acanthopores small and scarce, or wanting. Ord.–Dev.

62. **E. mutabilis** Ulrich. (Fig. 188, *f*, 190, *f*.) Ordovicic.

Slender, branching, cylindrical stems averaging 3.5 to 4.5 mm. in diameter. Apertures very oblique, especially in young specimens. Small maculæ commonly present in older stems. Axial portion of tubes with diaphragms distant about twice their diameter.

Trenton of Minnesota, Iowa, Wisconsin, Kentucky, Tennessee, Ohio and Canada.

Fig. 189. *Bythopora spinulosa*, enlarged.

63. **E. similis** Bassler. Siluric.

Zoarium apparently free, consisting of a pointed basal portion growing upward into branching stems.

Niagara (Rochester) of Western New York and Ontario.

XL. Stenopora Lonsdale.

Form varying from ramose to laminar or encrusting, with or without monticules, and with wall of the zoœcia periodically thickened in the mature region; diaphragms perforated centrally; few, irregularly distributed mesopores and large acanthopores. Miss.–Mid-Carb.

64. **S. carbonaria** (Worthen). (Fig. 190, *g*.) Carbonic.

Subcylindrical branches 10 to 15 mm. in diameter; surface smooth, no cell clusters; apertures angular to subcircular, frequently thick-walled, with numerous acanthopores and few mesopores.

Coal measures of Illinois, Kansas and Ohio.

XLI. Constellaria Dana.

Erect, flattened branches or fronds from an attached basal expansion; surface with depressed stellate maculæ, the spaces between rays elevated and bearing two or three short rows of closely

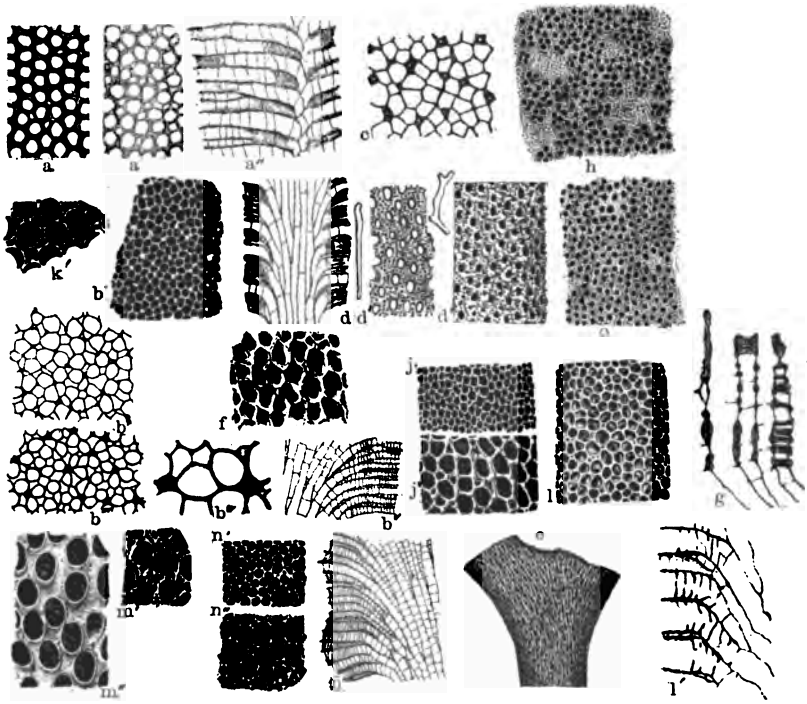


Fig. 190. *a*, *Petalotrypa compressa*, tangential sections with few, and with many mesopores, *a''*, vertical section, × 9; *b*, *Dekayella praenuntia*, *b'*, var. *echinata*, surface × 4½; *b''*, var. *multipora*, thin-walled, small acanthopores, × 9; *b'''*, same, thick-walled, large acanthopores, × 9; b^{iv}, same, × 25; b^{v}, same, vertical section, × 9; *c*, *Dekayia aspera*, tangential section, × 9; *d*, *Batostomella spinulosa*, × ½, and vertical section, tangential section and surface, × 9; *e*, *Bythopora herricki*, × 4½; *f*; *Eridotrypa mutabilis*, surface, × 4½; *g*, *Stenopora carbonaria*, vertical section, × 9, *h*, *Constellaria varia*, surface, × 4½; *j*, *Batostoma winchelli*, surface, × 4½ and × 9 *k*, *B. fertile*, *var. circulare*, surface, × 9; *l*, *Hemiphragma tenuimurale*, surface with incomplete diaphragms, × 4½; *l'*, part of vertical section, × 9; *m*, *Stromatotrypa ovata*, surfaces of two different layers (*m'* and *m''*), × 9; *n*, *Callopora multitabulata*, *n'*, surface, × 4½; *n''*, surface showing zoœcial covers, × 9; *n'''*, vertical section, × 9; *o*, *Nicholsonella pulchra*, surface × 4½. (All after Ulrich.)

approximated apertures; mesopores aggregated into maculæ with crowded diaphragms. Ordovicic.

65. **C. varia** Ulrich. (Fig. 190, *h.*) Ordovicic.

Flattened branches with large, irregularly stellate maculæ very slightly depressed; zoœcial apertures in clusters of from 4 to 10 each, slightly or not at all elevated; apertures subcircular.

Trenton of Minnesota, Canada and Tennessee.

66. **C. florida** Ulrich. (Fig. 188, *i.*) Ordovicic.

Flattened branches covered with crowded "stars," the rays sharp, petaloid and strongly elevated.

Lorraine of Cincinnati, Ohio, Indiana, Kentucky and Tennessee. Common.

XLII. NICHOLSONELLA Ulrich.

Laminar expansions, sometimes giving off flattened intertwining branches or fronds; interzoœcial spaces wide, with numerous mesopores, having thicker and more numerous diaphragms than zoœcial tubes, but obliterated with age by filling of secondary calcareous deposit. Ord.–Sil.

67. **N. vaupeli** Ulrich. Ordovicic.

Flattened, inosculating expansions with evenly distributed, low monticules of larger pores than ordinary, with center free from pores.

Lorraine of Cincinnati region.

68. **N. pulchra** Ulrich. (Fig. 188, *o*, 190, *o'*.) Ordovicic.

Irregular, flattened branches, monticules faint and often indefinite; interzoœcial space papillose.

Stones River of Tennessee.

XLIII. BATOSTOMA Ulrich.

Irregular branches from large basal expansion; zoœcia thin-walled in immature and thick in mature region, ring-like in section, with diaphragms; mesopores irregular; acanthopores large. Ordovicic.

69. **B. winchelli** Ulrich. (Fig. 188, *j*, 190, *j.*) Ordovicic.

Subcylindrical or slightly compressed branches 4 to 10 mm. in diameter, with rounded or subangular zoœcial apertures with ridge-like walls bearing acanthopores. Mesopores few.

Black River of Minnesota.

70. **B. fertile** Ulrich. (188, *k*, 190, *k.*) Ordovicic.

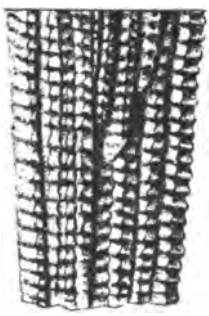
Large, of coarse, compressed branches, with round or polygonal

apertures and often few mesopores. Clusters of larger zoœcia enclose a stellate macula scattered over surface.

Stones River of Minnesota.

a

b



c

FIG. 191. *Monotrypa tabulata*. *a*, fragment, × 1; *b*, tangential section, ×6, *c*, enlargement of a group of tubes showing corrugations. (After Hall.)

71. **B. (Hemiphragma) tenuimurale** Ulrich. (Fig. 190, *l*.) Ordovicic.

Cylindrical or compressed stems with thin-walled polygonal apertures, without acanthopores and few mesopores; diaphragms in peripheral region incomplete.

Galena of Minnesota.

72. **B. (Hemiphragma) whitfieldi** (James). Ordovicic.

Like preceding, but more robust, and with crinkled walls, readily seen on broken surface.

Utica horizon of the region about Cincinnati.

XLIV. STROMATOTRYPA Ulrich.

Encrusting, with short zoœcia, oval in cross section and with few diaphragms.

Walls thin, with periodically constricted tubuli, one or more to each zoœcium. Oval apertures with minutely papillose peristomes separated by depressed interspaces. Closely tabulate mesopores, rarely showing on surface.

73. **S. ovata** Ulrich. (Fig. 188, *m*, 190, *m'*.) Ordovicic.

Encrusting shells or other Bryozoa, rarely free; without monticules, but with smooth areas of more widely separated apertures.

Stones River and Black River of Minnesota and Wisconsin.

XLV. MONOTRYPA Nicholson.

Massy hemispheric or discoidal, zoœcia comparatively large prismatic, with thin and often crinkled walls throughout; dia-

phragms remote; no mesopores or acanthopores; mature and immature regions indistinguishable. Ord.–Sil.

74. **M. tabulata** (Hall). (Fig. 191, *a–c.*) Lower Devonic.

Spheroidal or hemispheric; tubes polygonal, with thin and strongly corrugated walls, the corrugations forming nodes at the angles.

Helderberg (Coeymans and Port Ewen) of New York, etc.

75. **M. ? amplectens** Grabau. (Fig. 192 *a–d.*) Devonic.

Encrusting brachiopod shells, generally large Spirifers on which species of Aulopora have grown. The openings of the Aulopora

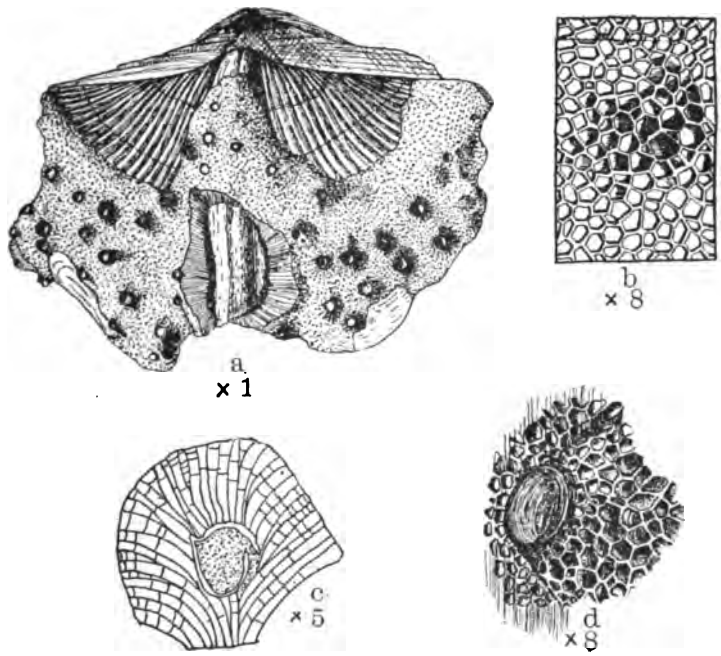


FIG. 192. *Monotrypa amplectens.* *a*, encrusting *Spirifer* shell to which are attached tubes of *Aulopora*, × 1; *b*, surface, × 8; *c*, vertical section enclosing *Aulopora*, × 5; *d*, surface surrounding mouth of *Aulopora*, × 8.

tubes are scattered among the apertures of the bryozoan, similar to the "Caunopora" type of Stromatoporoids. Sometimes on other corals.

Surface with monticules of larger apertures at regular intervals; apertures angular; walls finely striated; diaphragms remote in older, more closely set in outer part of tube.

Hamilton of Western New York and Michigan.

XLVI. Trematopora Hall.

Zoarium ramose; surface smooth or with monticules; zoœcia thin walled, the contact lines of walls of adjoining zoœcia distinct; diaphragms few, in the proximal end of zoœcia; apertures circular or oval with a more or less well-marked peristome; interspaces solid; mesopores irregularly angular, often obscurely moniliform, with diaphragms at the constricted parts; acanthopores of medium or small size usually present.

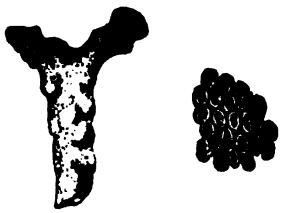


Fig. 193. *Trematopora tuberculosa* with enlargement of surface.

76. **T. tuberculosa** (Hall). (Fig. 193.) Siluric.

Irregularly ramose and stout branches; tuberculous monticules; tubular cells with oval apertures and thin elevated calicle or margin which is spinulose (bearing acanthopores); interapertural spaces solid, but separate below.

Rochester shales of New York.

XLVII. Callopora Hall.

Branching, and frequently anastomosing into bushy clumps, with prismatic zoœcia which later become, in most cases, cylindrical, and have their apertures operculated; diaphragms closely set except in central part of tube, and crowded in the angular mesopores. Ord.–Sil.

77. **C. multitabulata** (Ulrich). (Fig. 188, *n*, 190, *n*.) Ordovicic.

With strongly elevated monticules, few mesopores and numerous diaphragms.

Black River and Trenton of Kentucky, Tennessee, Minnesota, Canada, etc.

78. **C. ramosa** (d' Orbigny). (Fig. 194, 1.) Ordovicic.

Forming large clusters of stout, irregular, cylindrical stems, with strong, sharp monticules subregularly arranged, rarely uniting into ridges.

Common in the Lorraine of the Cincinnati region.

79. **C. dalei** (E. and H.) (Fig. 194, 3.) Ordovicic.

Branches more slender than preceding and with less prominent monticules, which sometimes unite into ridges, as in the next species.

Lorraine beds of the Cincinnati region.

80. **C. rugosa** (E. and H.) (FIG. 194, 2.) Ordovicic.

Of the type of *C. ramosa*, but the monticules united into prominent transverse ridges with zoœcial apertures.

Lorraine beds of the Cincinnati region.

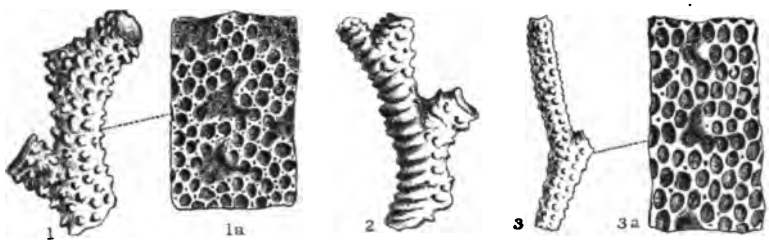


FIG. 194. 1, *Callopora ramosa*, × 1; 1*a*, enlargement of surface; 2, *C. rugosa*, × 1; 3, *C. dalei*, × 1; 3*a*, surface enlarged. (After Nicholson.)

81. **C. elegantula** Hall. (FIG. 195, *a–b*.) Siluric.

Branches solid, extremities often hollow or cup-like, apertures circular, the opercula with central perforation and radiating ridges.

Niagara of New York, Ontario, Indiana, Illinois, etc.

FIG. 195, *a*. *Callopora elegantula* with enlargements of surface and individual tubes.

FIG. 195, *b*. *Callopora elegantula*, a fragment much enlarged.

ORDER CRYPTOSTOMATA Vine.

XLVIII. PHYLLOPORINA Ulrich.

Irregularly anastomosing branches, with two to eight rows of apertures on one side, the other longitudinally striated; tabulated interspaces, closed at the surface, generally present; acanthopores often present. Ord.–Sil.

82. **P. reticulata** (Hall). (FIG. 201, *a*.) Ordovicic.

Generally as fragments of depressed, funnel-shaped zoarium with rounded branches 0.2 to 0.3 mm. in diameter, frequently and regularly inosculating; fenestrules about as wide as branches; three

FIG. 196. *Phylloporina asperato-striata* with enlargement of celluliferous and non-celluliferous faces, the latter showing the asperate-striate character.

irregular rows of zoœcia with subcircular apertures and numerous acanthopores; reverse side finely striated.

Black River and Trenton of New York, Vermont, Minnesota and Canada.

83. **P. asperato-striata** (Hall). (FIG. 196.) Siluric.

Oval, somewhat unequal fenestrules; outer face roughly striated, inner with three, four or more rows of subangular cells in obliquely parallel lines.

Rochester shale of New York, Canada, etc.

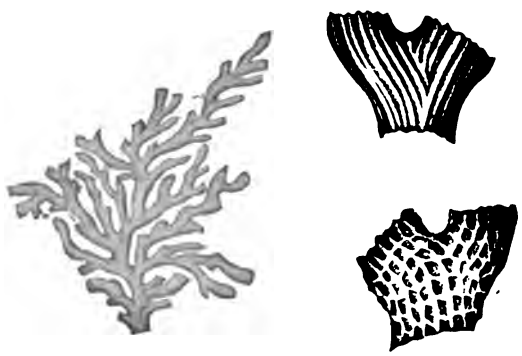


FIG. 197. *Drymotrypa diffusa* with celluliferous sides enlarged.

XLIX. DRYMOTRYPA Ulrich.

Dichotomously and frequently branching, longitudinally striate on one side, and on the other with several ranges of tubular zoœcia

springing from a thin double plate; vestibules expanding from orifices to angular apertures. Ord.–Sil.

84. **D. diffusa** (Hall). (FIG. 197.) Siluric.

Several stems originate from a common base, forming a shrubby frond; stems frequently bifurcate and spread laterally; apertures quadrangular or subrhomboidal.

Rochester shale of New York.

L. FENESTELLA Lonsdale.

Fan or funnel-shaped reticulated expansion of straight or flexuous rigid branches, apertures united by non-celluliferous cross-bars or dissepiments at regular intervals; two rows of apertures on the inside of branches, separated by a plain or tuberculated median keel. Ord.–Carb.

85. **F. elegans** Hall. (FIG. 198.) Siluric.

Carina subdued, apertures with longer diameter oblique to direction of branches, which are slender and frequently bifurcating, and are united by thin dissepiments; fenestrules on non-celluliferous side oblong-quadrangular, rarely oval.

Niagara of New York, Canada, etc.

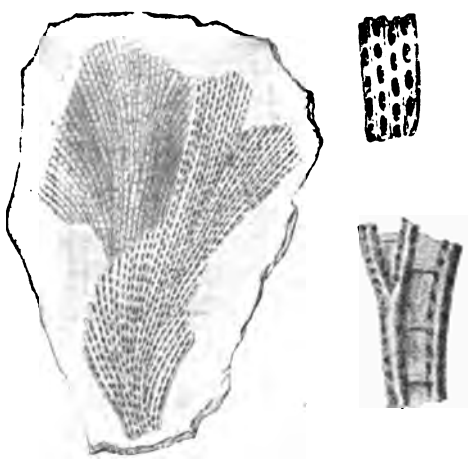


FIG. 198. *Fenestella elegans* with enlargements.

86. **F. crebripora** Hall. Lower Devonic.

Fenestrules wider than branches which are connected by dissepiments, slightly enlarging at contact; keel faint; non-celluliferous side finely striated.

Helderbergian of Eastern New York, etc.

87. **F. emaciata** Hall. (FIG. 199.) Mid-Devonic.

Large funnel-shaped; dissepiments thin and oblique; keel prominent; apertures closely and regularly disposed.

Hamilton of New York.

88. **F. cestriensis** Ulrich. (FIG. 201, *c*.) Mississippian.

Branches irregularly dividing, slightly flexuose; carina angular; apertures circular, with peristomes; reverse side rounded, smooth exept for scattered nodes.

Chester of Mississippi Valley, Kentucky, etc.

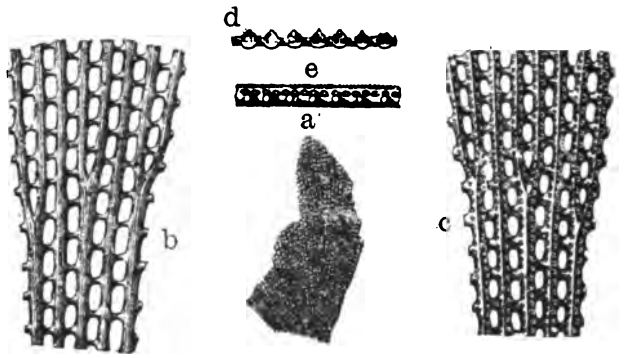


FIG. 199. *Fenestella emaciata*. *a*, fragment of frond (reduced); *b*, non-celluliferous face showing striated branches and oblique dissepiments, ×4; *c*, celluliferous face, ×4; *d*, transverse section of branches, ×4; *e*, lateral view of branches, showing position of apertures, ×4. (After Hall.)

89. **F. tenax** Ulrich. (FIG. 201, *b*.) Mississippian.

Fenestrules narrower than branches; dissepiments moderately thick; no nodes, but faint striations on reverse side; apertures circular, with peristomes.

Chester of Mississippi Valley and Kentucky; Waverly of Ohio.

LI. SEMICOSCINIUM Prout.

Funnel-shaped, all openings on outer side, wide, short dissepiments, the branches appearing to anastomose on non-poriferous face, whose fenestrules are subrhomboidal or rounded; apertures in two rows; median keel very high, expanded at the summit. Sil.–Dev.

90. **S. tenuiceps** (Hall). (FIG. 200.) Siluric.

Carina sharp and thin; transverse dissepiments do not extend as high as the branches, sometimes scarcely visible; apertures

large, round, opening laterally; fenestrules oval on non-celluliferous side, which is striated, but appears granular when worn.

Rochester shale of New York, Canada, etc.

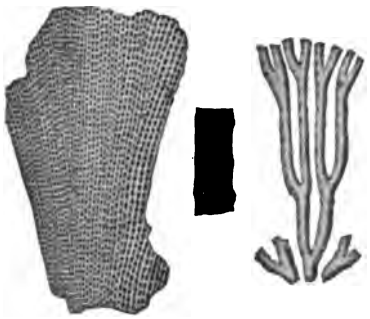


FIG. 200, *a*. *Semicoscinium tenuiceps*. Clinton; with enlargements.

FIG. 200, *b*. *Semicoscinium tenuiceps*. Niagara; enlargements of celluliferous and non-celluliferous faces.

91. **S. planodorsatum** Ulrich. (FIG. 201, *d*.) Devonic.

Fenestrules very small; carina prominent, with circular apertures; reverse side flat, with irregularly oval to circular fenestrules, showing no evidence of branching.

Hamilton of Falls of the Ohio.

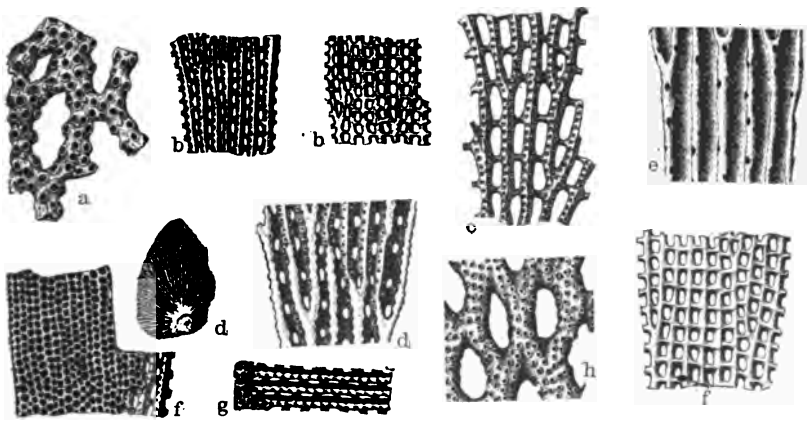


FIG. 201. *a*, *Phylloporina reticulata*, × 9; *b*, *Fenestella tenax*, obverse and reverse faces, × 4½; *c*, *F. cestriensis*, obverse face, × 4½; *d*, *Semicoscinium planodorsatum*, obverse side, × ½ and × 4½; *e*, *Fenestrapora occidentalis* obverse, × 4½; *f*, *Hemitrypa proutana*, non-celluliferous and celluliferous faces, the latter with part of superficial network, × 4½; *g*, var. *nodulosa*, × 4½; *h*, *Reteporidra perundata*, obverse face, × 4½. (After Ulrich.)

LII. Fenestrapora Hall.

Differs from *Semicoscinium* in the reverse of the zoarium and the expanded summits of the carinæ, furnished with large scattered pores or pits. Devonic.

92. **F. occidentalis** Ulrich. (Fig. 201, *e*.) Devonic.

Fenestrules oval; carina angular and expanded; the irregularly disposed pits on the side, rather few in number; frond rather coarse.

Hamilton of Iowa.

LIII. Unitrypa Hall.

Differs from *Fenestella* in having the prominent carinæ thickened above and connected by thin, oblique, subimbricating plates (scalæ) varying from two to each fenestrule to the number of zoœcia. Sil.–Dev.

93. **U. scalaris** Hall. (Fig. 202, *a–g*.) Devonic.

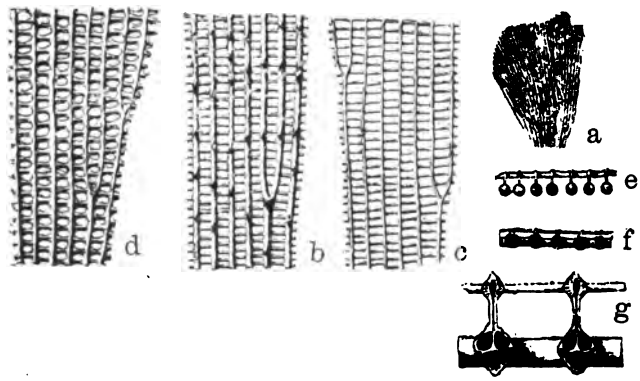


Fig. 202. *Unitrypa scalaris*. *a*, fragment of carinæ and scalæ; *b*, summits of carinæ and scalæ, showing nodes on former, × 4; *c*, fragment showing thin carinæ and scalæ, × 4; *d*, fragment showing under side of carinæ and scalæ, × 4; *e*, *f*, transverse sections of different fronds, × 4; *g*, transverse section much enlarged to show rhomboidal sections of branches, with dissepiment connecting them, the thin expanding carinæ connected by scalæ. (After Hall.)

Branches straight, parallel and rigid, the carinæ and scalæ making a ladder-like structure, the carinæ projecting above the very oblique scalæ.

Hamilton of New York and Ontario.

94. **U. acaulis** Hall. Devonic.

Scalæ very slender and closely disposed; summit of carina very prominent, sometimes noded. Length and width of fenestrules on celluliferous face as 3 to 1; on non-celluliferous, as 2 to 1.

Hamilton of Falls of the Ohio.

LIV. Loculipora Hall.

Funnel-shaped, dissepiments non-poriferous, reduced to a minimum, carinated like the branches; the carinæ coalesce and expand at the summits, their width usually equalling that of branches and dissepiments. Sil.–Dev.

95. **L. perforata** (Hall). (Fig. 203.) Devonic.

Frond regularly reticulated, the fenestrules oval in a depressed hexagonal surface, and each surrounded by nine or ten apertures.

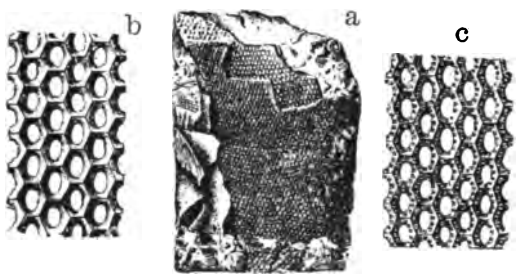


Fig. 203. *Loculipora perforata*. *a*, fragment showing manner of growth; *b*, non-celluliferous face, showing angular slightly carinated branches and dissepiments, × 4; *c*, celluliferous face, × 4. (After Hall.)

The expansion of the carina may make this face appear like the non-poriferous face.

Hamilton of New York.

LV. Hemitrypa Phillips.

Differs from *Fenestella* in a reticulated superstructure, whose meshes correspond in position and numbers to the zoœcial apertures, and resting on pillars which rise at regular intervals from the moderate median keel of the branches. Sil.–Carb.

96. **H. proutana** Ulrich. (Fig. 201, *f*, *g*.) Mississippian.

Superficial network of longitudinal bars, united by short transverse bars, the former strong over the branches and weaker over the interspaces of the underlying frond, the latter alternating in posi-

tion on opposite sides of each weaker longitudinal bar. The underlying branches have each a low carina with circular pores with peristomes, on either side, and are connected by depressed dissepiments half as wide as the branches.

Keokuk of Illinois and Iowa; Warsaw of Illinois and Missouri; St. Louis of Kentucky.

LVI. RETEPORIDRA Nickles and Bassler.

Flabellate or undulating expansion with thickened margins, the sinuous or zigzag non-carinate branches anastomosing at short and regular intervals, producing a regular series of oval fenestrules; apertures in three to seven rows, non-celluliferous side not striated.

97. **R. perundata** (Hall). (Fig. 201, *h*.) Mid-Devonic.

Fenestrules oval, irregular, non-celluliferous face angular or carinated, celluliferous rounded; cell apertures in from three to five ranges.

Hamilton of Western New York, etc.

LVII. ARCHIMEDES Owen.

Like *Fenestella*, but spirally wound and supported by a solid calcareous central axis, which is often the only part remaining intact.

98. **A. communis** Ulrich. (Fig. 205, *b'*.) Mississippian.

Central axis or "screw" long, slender (1 to 2 mm. in diameter) and uniformly coiled, 7 or 8 volutions in 20 mm., the fenestrated portion forming an angle of from 85 to 90 degrees with axis. (*A. intermedius* Ulrich makes an angle of 72 degrees and has somewhat fewer whorls. *A. swallowanus* varies from 2.8 to 6.7 mm. in diameter, and has an average of 5 volutions to 20 mm., the angle of divergence of the fenestrated portion being 85 degrees. *A. proutanus* Ulrich has from 5 to 7 volutions in 20 mm., and an angle of 65 degrees for the fenestrated part. It is somewhat thinner than *A. communis*.)

Chester of Kentucky and Illinois.

99. **A. wortheni** (Hall). (Fig. 205, *a*.) Mississippian.

Screw large and coarse (5 and 10 mm. in diameter), volutions either right- or left-handed, from 5 to 6 in 50 mm., fenestrated portion diverging at an angle of about 65 degrees. Zoœcia separated by strong spinose carina.

Warsaw of Illinois.

100. **A. laxus** Hall. Mississippian.

Very loosely coiled, axis formed of thickened edge of frond, one volution in 25 mm. or more; angle of fenestrated portion acute.

Chester of Illinois and Kentucky.

101. **A. sublaxus.** (Fig. 205, *b.*) Mississippian.

About half the size of the preceding.

Chester of Illinois.

102. **A. terebriformis** Ulrich. Mississippian.

Differs from *A. communis* in being more slender, with from 3 to 4 volutions in 20 mm. In coiling resembles *A. laxus.* Angle of divergence 60 to 65 degrees.

Chester of Illinois and Kentucky.

LVIII. POLYPORA McCoy.

Differs from *Fenestella* in having from two to eight rows of zoœcia on a branch, and the median keel reduced to a row of strong nodes or tubercles, or absent altogether. Sil.–Carb.

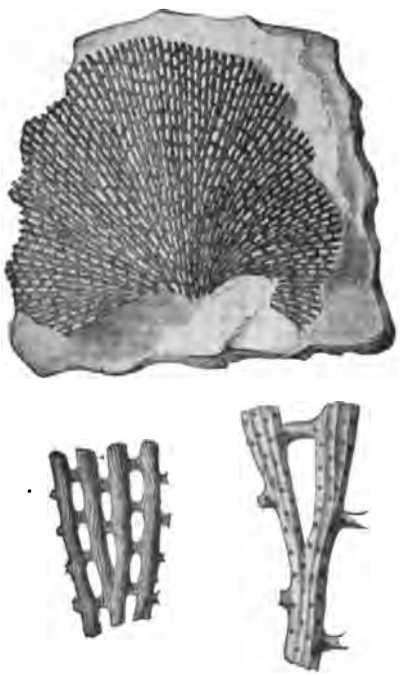


FIG. 204. *Polypora incepta* with non-celluliferous and celluliferous faces enlarged.

103. **P. incepta** Hall. (Fig. 204.) Siluric.

Branches regularly dividing with flexuous striæ on the non-celluliferous side, and several strong ridges separating the three or

four rows of oval and alternating apertures, on the celluliferous side; dissepiments thin, scarcely thickened at junction with branches.

Rochester shale of New York and Canada.

104. **P. fistulata** (Hall). Mid-Devonic.

Two to three rows of apertures with strong peristomes; fenestrules oval, dissepiments expanding at the ends.

Hamilton of New York and Ontario.

105. **P. shumardi** Prout. (*P. cultellata* Hall). Mid-Devonic.

Strong branches united by their dissepiments, forming narrow fenestrules on celluliferous side, where branches are marked by sharp nodes, and have from three to seven ranges of apertures; reversed side with broad oval fenestrules, and a faint keel or nodes, or smooth.

Hamilton of Falls of the Ohio.

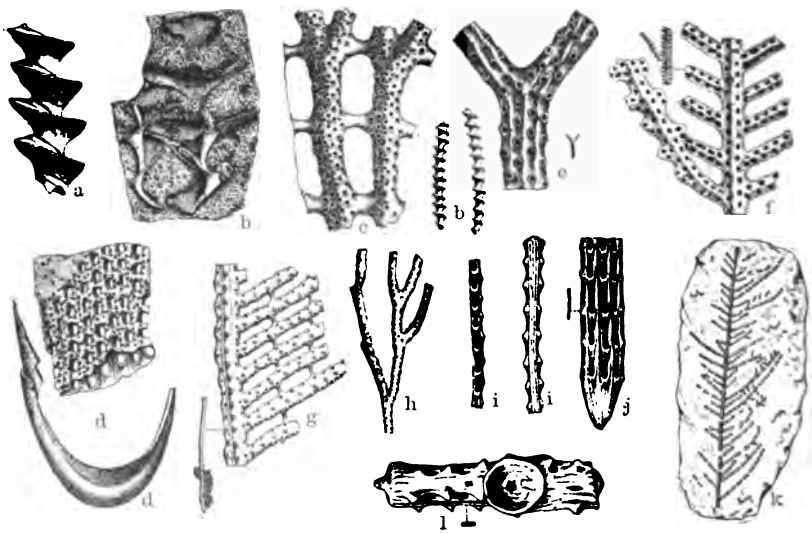


FIG. 205. *a*, *Archimedes wortheni*, ×½; *b*, *A. sublaxus*, showing fenestrated portions, × ½; *b'*, *A communis*, two specimens, × ½; *c*, *Polypora submarginata*, obverse face, ×4½; *d*, *Lyropora quinconcialis*, poriferous face, ×4½, *d'*, obverse side of basal support, × ½; *e*, *Thamniscus furcillatus*, obverse face, × ½ and × 9; *f*, *Pinnatopora conferta*, × ½ and ×4½; *g*, *Ptilopora cylindracea*, obverse face, × ½ and ×4½; *h*, *Diploporaria bifurcata*, × 4½; *i*, *Arthrostylus obliquus*, lateral and non-celluliferous aspect, × 9; *j*, *Helopora spiniformis*, × ½ and × 9; *k*, *Arthroclema billingsi*, frond, × ½; l, *A. armatum*, segment of primary series with articulating socket, × ½ and × 9. (After Ulrich.)

106. **P. submarginata** Meek. (Fig. 205, *c.*) Carbonic.

Branches convex with a row of spines or tubercles, and five ranges of apertures; five or six apertures to a fenestrule, the latter irregular, elongate oval; dissepiments thin.

Upper Coal Measures of Nebraska, Iowa and Illinois.

LIX. Thamniscus King.

Branches like those of Polypora, but bifurcating more freely and rarely or not at all connected by dissepiments. Sil.–Carb.

107. **T. furcillatus** Ulrich. (Fig. 205, *e.*) Mississippian.

Branches small, with three to four ranges of apertures, with continuous or discontinuous low ridges between.

A characteristic species of the Chester group of Illinois and Kentucky.

LX. Lyropora Hall.

Flabellate, the fenestrated portion spread between the arms of a non-poriferons U- or V-shaped calcareous support, which is free or pedunculate at the base; zoœcia in from two to five ranges; no median keel. Miss.

108. **L. quincuncialis** (Hall). (Fig. 205, *d.*) Mississippian.

U-shaped support narrow oval in cross section; fenestrules irregularly oval; two or three ranges of apertures; stout dissepiments, which, on the non-celluliferous side, are often stronger than the branches, forming transverse ridges.

Chester of Illinois and Kentucky.

LXI. Fenestralia Prout.

Differs from Fenestella in having four rows of apertures, two on each side of prominent keel. Miss.

109. **F. sancti-ludovici** Prout. Mississippian.

Branches with strong central carinæ dilated into tubercles at intervals; fenestrules oblong, subquadrangular; two ranges of apertures on each side of carina; dissepiments about two-thirds the width of the branches.

Warsaw and St. Louis of Missouri and Illinois.

LXII. Pinnatopora Vine.

Small, delicate stipe, and short, free lateral branches given off at regular, intervals; apertures in two rows on one face only, separated by a moderate median keel. (Glauconome of authors.) Dev.–Carb.

110. **P. carinata** (Hall.) (*Glauconome carinata* Hall.) (Fig. 206.) Devonic.

Small, with broad central rachis, and alternating thin, short lateral branches; non-celluliferous face with three prominent carinæ; apertures circular, with comparatively strong peristomes and prominent carinæ between the ranges.

Hamilton of Western New York, etc.

FIG. 206. *Pinnatopora carinata* × 6. (After Hall and Simpson.)

111. **P. conferta** Ulrich. (Fig. 205, *f.*) Mississippian.

Central rachis, and branches more nearly of the same width; branches nearly opposite close-set; two ranges of close-set pores on rachis and branches, separated by low ridges.

Keokuk of Iowa and Illinois.

LXIII. PTILOPORA McCoy.

Differs from the preceding in having the stipe much stronger than the oblique lateral branches, which are occasionally and irregularly united by dissepiments. Dev.–Miss.

112. **P. striata** Hall. Devonic.

Branches rigid, diverging at angles of 45 degrees, and separated by a space twice their width; dissepiments thin, irregular; apertures in two ranges.

Hamilton of Western New York and Ontario.

113. **P. cylindracea** Ulrich. (Fig. 205, *g.*) Mississippian.

Differs from the preceding in having a row of hollow nodes and a median ridge on the rachis, and a similar row without the ridge on the branches, and very thin, depressed, regular dissepiments.

Keokuk of Iowa and Kentucky.

LXIV. DIPLOPORARIA Nickles and Bassler.

Like *Pinnatopora*, but without the lateral branchlets. Miss.–Coal Meas.

114. **D. bifurcata** (Ulrich.) (Fig. 205, *h.*) Mississippian.

Small, cylindrical stipes (0.3 mm. in diameter) bifurcating at

regular intervals; apertures in two ranges on sides of stipe; reverse of branches finely striated.

Chester of Illinois, etc.

LXV. Arthrostylus Ulrich.

Bushy, dichotomously divided branches which consist of numerous, exceedingly slender, equal subquadrate segments, united by terminal articulations; one face longitudinally striated, the other three (sometimes less) with a linear series of apertures generally between longitudinal ridges. Ord.

115. **A. obliquus** Ulrich. (Fig. 205, *i.*) Ordovicic.

Segments needle-shaped, about 4 mm. long; subquadrangular in section (0.2 × 0.15 mm.) slightly expanding to extremity; apertures oblique, lower border prominent; no ridges between ranges.

Stones River of Minnesota.

LXVI. Helopora Hall.

Differs from preceding in its larger segments, which have zoœcial apertures on all sides. Ord.–Sil.

116. **H. spiniformis** (Ulrich). (Fig. 205, *j.*) Ordovicic.

Segments 5 to 10 mm. in length, obtusely pointed at the ends; apertures oblique on all sides, in from 8 to 16 longitudinal ranges, and separated by slightly elevated lines.

Stones River of Tennessee and Illinois.

117. **H. fragilis** Hall. (Fig. 207.) Siluric.

Swollen at one end, apertures oval or subangular, having a spiral direction around the stipe; length 5–6 mm.

Fig. 207. *Helopora fragilis*, natural size and enlarged.

Clinton and Niagara of New York and Ontario.

LXVII. Arthroclema Billings.

Segments celluliferous on all sides, articulated laterally and terminally in a pinnate manner; apertures oval in series between longitudinal ridges. Ord.

118. **A. armatum** Ulrich. (Fig. 205, *l.*) Ordovicic.

Of three sets of joints, secondary and tertiary more slender than primary which have sharply-defined articulating sockets, and small apertures in six ranges with strong spines near each; secondary segments with apertures in five or six ranges between strong ridges, and with lower lip spiniform.

Trenton of Minnesota, etc.

119. **A. billingsi** Ulrich. (Fig. 205, *k.*) Ordovicic.

Primary segments 3.5 to 4 mm. long, each with two secondary segments (4 mm. long) upon each side (4 in all), the succeeding ones 2 mm. long; apertures subquadrate, 6 in 2 mm.

Trenton of Canada.

LXVIII. Nematopora Ulrich.

Slender, ramose, with pointed basal extremity, not jointed; subtubular zoœcia arranged radially around one or two minute axial tubes, with oval or subcircular apertures, and peristomes generally in linear series between longitudinal ridges. Ord.–Dev.

120. **N. ovalis** Ulrich. (Fig. 208, *a.*) Ordovicic.

Bifurcating at intervals of 2 mm., diameter 0.3 to 0.4 mm.; large oval apertures, peristomes connected by short ridges, in four or five ranges.

Trenton of New York, Canada, and Minnesota.

LXIX. Rhombopora Meek.

Slender, non-articulate, and solid branches; apertures in longitudinally or diagonally intersecting series; rhombic or diagonal vestibules, in the region of which the zoœcia are thick walled; acanthopores sometimes of two types, large and small. Sil.–Carb.

121. **R. tenuirama** Ulrich. (Fig. 208, *b.*) Mississippian.

Branches 0.4 to 0.5 mm. in diameter; apertures oval, between slightly flexuous longitudinal ridges, carrying both large and small spines.

Chester of Illinois and Kentucky.

122. **R. lepidodendroides** Meek. Carbonic.

Average diameter of branches 1.75 mm., largest 3 mm.; zoœcia in regular quincunx order, oval, with rhombic vestibules, margined by a single or double row of spiniform tubuli, with a large spine at the angle.

Coal Measures of Nebraska, Kansas, Missouri, Iowa, Illinois, and Ohio. Rather common.

LXX. Cœloconus Ulrich.

Simple hollow expansions from an attenuated striated base; zoœcia short, with well developed hemisepta, and apertures in diagonally intersecting series. Miss.

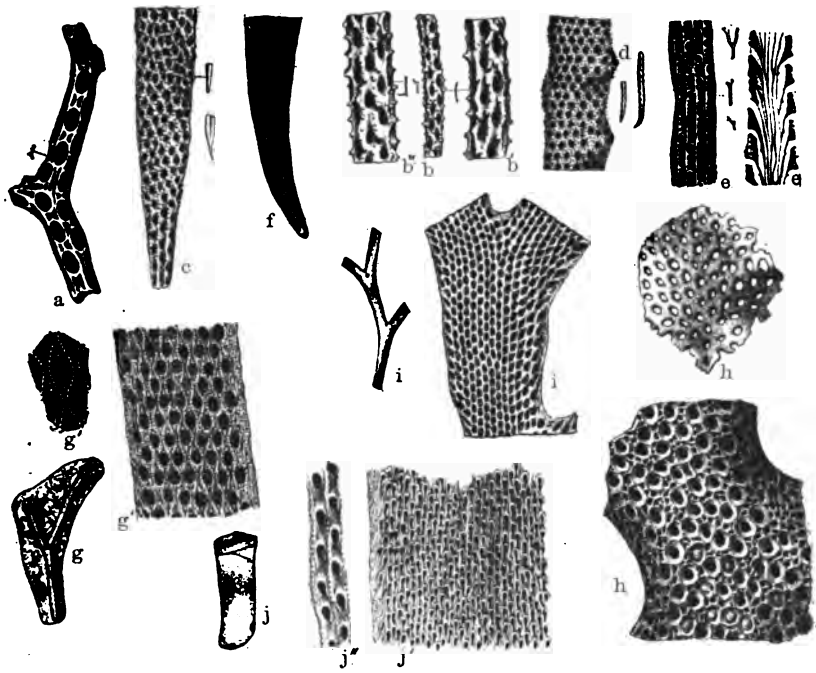


Fig. 208. *a*, *Nematopora ovalis*, × ½ and × 9; *b*, *Rhombopora tenuirama*, × ½ and × 6 and 12 (*b'*, *b''*); *c*, *Cœloconus granosus*, × ½ and × 6; *d*, *Bactropora simplex*, × ½ and × 6; *e*, *Streblotrypa nicklesi*, × ½ and surface and section, × 9; *f*, *Escharopora subrecta*, basal portion, × 4½; *g*, *Arthropora simplex*, × ½, and surface × 9, and × 18; *h*, *Stictoporella cribrosa*, × ½, and portion × 9; *i*, *Rhinidictya mutabilis*, × ½ and × 4½; *j*, *Phyllodictya varia*, × ½ (*j*), surface × 4½ (*j'*), and portion × 9 (*j''*). (All after Ulrich.)

123. **C. granosus** Ulrich. (Fig. 208, *c*.) Mississippian.

Lined on inside with thick epitheca; apertures oval to subcircular, the interspaces with granules; basal portion with vertical granulose ridges between the oval apertures.

Chester of Illinois.

LXXI. Bactropora Hall.

Like Rhombopora, but simple or only slightly branched, and with lower extremity pointed. Dev.–Miss.

124. **B. simplex** Ulrich. (Fig. 208, *d*.) Mississippian.

Surface with transversely elongated monticules, appearing often like annulations; apertures oval to subcircular; narrow interspaces with a single or double row of small acanthopores; average size 1.5 mm. in diameter by 18 mm. in length.

Keokuk of Iowa, Illinois, and Missouri.

LXXII. Streblotrypa Ulrich.

Ramose, slender, and solid, frequently bifurcating, with long tubular zoœcia diverging from the center, with hemisepta (inferior one best developed) and regularly elliptical apertures with peristomes usually arranged in longitudinal series; one to fifteen small pits below the apertures, and occasionally very small acanthopores.

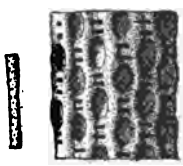


Fig. 209. *Streblotrypa hamiltonensis*, × 1, and × 18. (After Hall and Simpson).

125. **S. hamiltonensis** (Nicholson). (Fig. 209.) Devonic.

Apertures between prominent wavy longitudinal ridges, alternating in position in adjoining ranges, and having two angular pits between the apertures of each row.

Hamilton of Western New York and Ontario.

126. **S. nicklesi** Ulrich. (Fig. 208, *e*.) Mississippian.

Apertures small, between three straight longitudinal ridges, alternating; peristomes strongest anteriorly; interspaces with from nine to fifteen small pores in two or three rows.

Chester of Illinois and Kentucky.

LXXIII. Ptilodictya Lonsdale.

Simple, unbranched, lanceolate or falciform frond, articulating, with small basal expansion, and having zoœcia on both sides except the margin; zoœcia narrow oblong-quadrate and arranged longitudinally in the young and with additional variously formed zoœcia added in the adult; walls of vestibules thick, solid, and with a double row of minute dots. Ord.–Dev.

127. **P. nebulosa** (Hall). Lower Devonic.

A thin, leaf-like expansion from a thickened, narrow, striated base; rows of cells increase rapidly by intercalation; rounded monticules, separated by about 3 mm. from each other, mark the surface.

Helderbergian of New York, etc.

LXXIV. Escharopora Hall.

Like *Ptilodictya*, but with the apertures in decussating series, and surrounded by sloping hexagonal areas. Ord.

128. **E. falciformis** (Nicholson). Ordovicic.

Falciform, narrow and long, apertures rhombic to oval, in diagonal curved series.

Lorraine of the Cincinnati region and Tennessee.

129. **E. subrecta** (Ulrich). (Fig. 208, *f.*) Ordovicic.

Elongate narrow, straight or curved, flattened and tapering below; apertures oval, between regularly wavy ridges, which regularly approach and diverge; adult portion with a few mesopores, as in *Streblotrypa*.

Black River of Minnesota, Iowa and Wisconsin.

130. **E. pavonia** (d'Orbigny). Ordovicic.

Expanded, more or less irregular; apertures oval to subcircular, with hexagonal vestibules and low, obscure monticules of slightly larger cells; arrangement of cells in curved lines as in *E. falciformis*.

Lorraine beds of the Cincinnati region and Tennessee.

LXXV. Clathropora Hall.

Anastomosing branches forming regular network with round or oval fenestrules and pointed articulating base, apertures on both sides usually subquadrate, arranged longitudinally. Sil.–Dev.

131. **C. frondosa** Hall. (Fig. 210.) Siluric.

Flabellate or funnel-shaped fronds; apertures rhomboidal or oblong quadrangular, opening obliquely upward.

Clinton of Ohio; Niagara of Western New York and Ontario.

LXXVI. Arthropora Ulrich.

Bushy, of numerous articulating equal segments spread in a plane; apertures on both sides, elliptical, surrounded by delicate

peristomes, and with interspaces marked by variously disposed thread-like ridges and a row of minute papillæ. Ord.

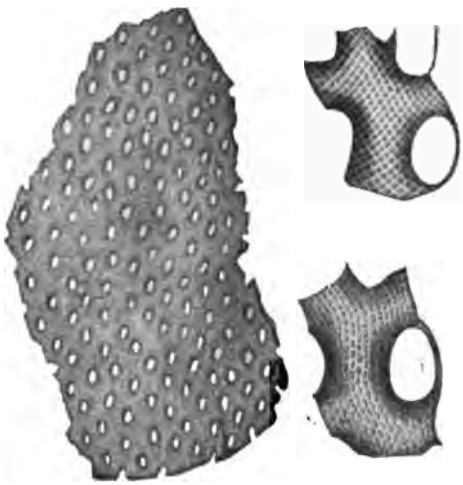


FIG. 210. *Clathropora frondosa*, with portions of celluliferous face enlarged. (Hall.)

132. **A. simplex** Ulrich. (Fig. 208, *g*.) Ordovicic.

Jointed, but generally found in isolated unbranched segments, 12 to 19 mm. long and 1 to 1.8 mm. wide; margins free from apertures; longitudinal wavy and papillose ridges, alternately converging and diverging, surround the apertures.

Stones River and Black River of Minnesota and Iowa.

133. **A. shafferi** Meek. Ordovicic.

Segments flat, branching repeatedly; apertures oval, rather distant; interspaces with from one to four wavy raised lines, visible under high power.

Lorraine of the Cincinnati region.

LXXVII. STICTOPORELLA Ulrich.

Branching and leaf-like, nonarticulate from spreading base; zoœcia on both sides, with primitive portion tubular, usually long, generally without any septa, except occasionally an inferior one; orifices at bottom of wide sloping vestibule; thick walled, untabulated mesopores on margins of frond and between apertures. Ord.

134. **S. cribrosa** Ulrich. (Fig. 208, *h*). Ordovicic.

Fenestrules at irregular intervals and varying greatly in size and form; apertures small, subcircular or elliptical, with sharply defined

polygonal or circular vestibules and numerous small mesopores, which often completely surround the zoœcia.

Stones River and Black River of Minnesota.

LXXVIII. Intrapora Hall.

Ramose from a spreading base with compressed and dichotomously divided branches; zoœcia on both sides, tubular, at first parallel to mesotheca, then bending abruptly outward; apertures oval, with peristome; minute angular pits, the openings of tabulated mesopores, in the interspaces, sometimes closed by calcareous tissue. Dev.–Miss.

135. **I. puteolata** Hall. Devonic.

Flattened, dichotomously branching frond, from spreading base; width usually 2 to 4 mm. but sometimes 20 mm. or more; oval apertures closely and irregularly disposed, frequently in contact, with strong peristomes, interspaces and margins with angular pits or mesopores.

Hamilton of Falls of the Ohio.

LXXIX. Coscinella Hall.

Explanate fronds of anastomosing branches from spreading base; zoœcia on both sides of frond, tubular, resting upon the mesotheca, with rather long direct vestibules and irregularly disposed circular apertures; spaces between vestibules and margins of fenestrules occupied by numerous tabulated mesopores which open on the surface as fine pits. Dev.

136. **C. elegantula** Hall and Simpson. Devonic.

Fenestrules irregular in form, size and distribution; apertures circular, with pronounced peristomes, generally separated by a single series of mesopores only.

Hamilton of Ontario.

LXXX. Rhinidictya Ulrich.

Bifoliate ramose, of narrow compressed bifurcating straight-edged branches with parallel margins, attached by continuous expanded base; apertures between longitudinal, slightly elevated or flexuous ridges, carrying a crowded row of small blunt spines; space around apertures sloping to summit of ridges. Ordovicic.

137. **R. mutabilis** Ulrich. (Fig. 208, *i.*) Ordovicic.

Branches commonly from 2.3 to 3.2 mm. wide, dividing at intervals of from 7 to 16 mm.; non-celluliferous margins often almost

wanting; zoœcia in 14 or 15 rows, the intervening ridges carrying granules; apertures direct.

Stones River to Trenton, Minnesota and Iowa.

138. **R. trentonensis** (Ulrich). Ordovicic.

Marginal apertures generally somewhat larger; interspaces thin, without granules; superior hemiseptum not developed.

Stones River of Tennessee, Minnesota, Wisconsin and Illinois.

LXXXI. Phyllodictya Ulrich.

Bifoliate, simple or irregularly branched, from an expanded attached base; long tubular zoœcia with diaphragms, but without hemisepta, bending very gradually outward from central axis, forming oblique apertures with posterior edge lip-like; wide subsolid interspaces, traversed vertically by minute tubuli, which appear as papillæ upon the surface. Ord.

139. **P. varia** Ulrich. (Fig. 208, *j*.) Ordovicic.

Leaf-like expansions, surface with smooth or finely granulated striate maculæ at 4 mm. intervals; apertures pyriform, oblique, with peristome strong posteriorly; granulose vertical ridges between the apertures.

Black River of Minnesota.

LXXXII. Pachydictya Ulrich.

Bifoliate, ramose, of narrow, bifurcating stipes with parallel margins; or irregular undulating fronds with acute non-poriferous margins; surface with small maculæ, surrounded by apertures slightly larger than the average; marginal rows of apertures sometimes larger than average; zoœcia thin-walled, elliptical or subquadrate, separated by small vesicles; vestibules direct, thick-walled, ring-like in section; interspaces with minute tubuli; one or more diaphragms present. Ord.–Sil.

140. **P. fimbriata** Ulrich. (Fig. 214, *a*.) Ordovicic

Branches from 2 to 5 mm. wide, with subparallel, wavy or ruffled non-poriferous margins; apertures in rows in central area, between lines of minute pores.

Black River of Minnesota and Stones River of Tennessee.

141. **P. acuta** (Hall). Ordovicic.

Differs from the preceding in its smooth non-poriferous margin

and the greater interspaces between the apertures, which are much larger near the margin than at the center.

Trenton of New York, Kentucky, Iowa, Minnesota and Manitoba.

142. **P. crassa** (Hall). Siluric.

Branches 2.5 to 3 mm. wide; cells elliptical, with strong peristomes and separated by slightly wavy ridges; a marginal row of larger apertures, with a non-celluliferous striated margin.

Clinton of New York, Ohio and Ontario; Niagara of New York; Anticosti group of Anticosti.

LXXXIII. CYSTODICTYA Ulrich.

Ramose, of two layers of cells grown back to back, cross sections elliptical; subparallel margins non-poriferous; apertures subelliptical in linear series between longitudinal ridges, with lunarium on marginal side of apertures; interspaces finely striated, granulose or smooth. Worn specimens show pits and cells. Dev.-Carb.

143. **C. gilberti** (Meek). (Fig. 214, *b*.) Devonic.

Repeatedly branching rows of apertures and separating ridges, increasing rapidly by interpolation on the branches.

Onondaga to Hamilton of Ohio and Ontario; Hamilton of Falls of the Ohio and Utica, Indiana.

144. **C. hamiltonensis** Ulrich. Devonic.

Branches bifurcating, 2.5 to 3 mm. wide; apertures nearly circular, alternating in adjoining rows.

Hamilton of Iowa, Illinois, Wisconsin, Western New York and Manitoba.

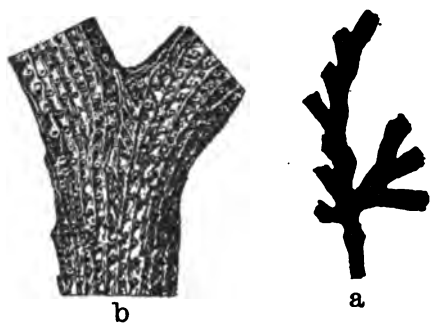


FIG. 211. *Cystodictya incisurata*. *a*, natural size, and *b*, portion enlarged. (After Hall and Simpson.)

145. **C. incisurata** (Hall). (Fig. 211.) Devonic.

Branches bifurcating from 2 to 6 mm. in width, margins parallel or slightly diverging; ridges continuous to the margin, where they often cause denticulations, slowly increasing by intercalation; apertures circular to oval or irregular; lunarium strong.

Hamilton of Central and Western New York and Ontario.

LXXXIV. Dichotrypa Ulrich.

Like *Cystodictya*, but in form a large, thin, bifoliate expansion, with solid maculæ on surface. Dev.–Miss.

146. **D. lyroides** Ulrich. (Fig. 214, *c*.) Mississippian.

Frond free, lyre-shaped, with thick, solid, rounded margins; surface with broad monticules, with solid circular or substellate maculæ, bordered by larger cells.

St. Louis of southern Kentucky.

LXXXV. Tæniopora Nicholson.

Differs from *Cystodictya* in having a strongly elevated, longitudinal central ridge on each face, making cross-section somewhat rhomboidal. Dev.

147. **T. exigua** Nicholson. (Fig. 212.) Devonic.

Non-celluliferous margin comparatively narrow, carinæ on main stem and branches strong, rounded; apertures circular, with strong peristomes.

Hamilton of Western New York and Ontario.

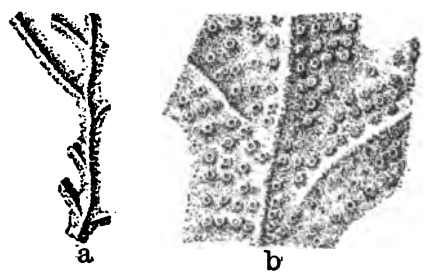


Fig. 212. *Tæniopora exigua*. *a*, fragment × 1; and *b*, small portion × 6. (After Hall and Simpson.)

148. **T. penniformis** Nicholson. Devonic.

Keel broader and more strongly elevated, and non-celluliferous margin wider, than in the preceding; apertures arranged in oblique transverse rows; peristomes pronounced.

Hamilton of Western New York and Ontario.

LXXXVI. Coscinium Keyserling.

Differs from *Cystodictya* in having the branches inosculating at short intervals, so as to produce broad fronds, perforated at rhythmic intervals by elliptical or circular fenestrules. Dev.–Carb.

149. **C. cribriforme** Prout. Devonic.

Cells tubular, very oblique, the apertures trilobate, or when worn, arched or subtriangular, closely and irregularly disposed; fenestrules varying greatly in size and distance from each other; lunarium elevated.

Hamilton of Falls of the Ohio and Utica Ind.

150. **C. latum** Ulrich. (Fig. 214, *d.*) Mississippian.

Branches wider than in preceding (4–5 mm.); cell apertures elevated and disposed in diagonal lines.

Burlington of Illinois and Iowa.

LXXXVII. Acrogenia Hall.

Segmented, arising from cylindrical rootlets, two segments from truncated ends of preceding one, each obconical and striated at the base, later becoming flattened and bearing apertures in linear series, separated by ridges, largest in marginal row; lunarium prominent. Dev.

151. **A. prolifera** Hall. (Fig. 213.) Devonic.

Apertures small and circular, with weak peristomes, and in rows, separated by continuous longitudinal ridges.

Hamilton of Central and Western New York.

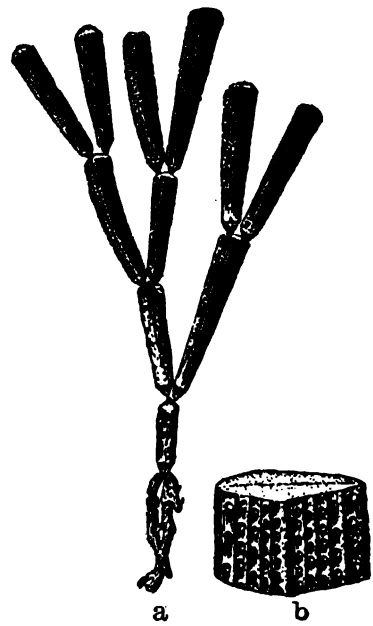


Fig. 213. *Acrogenia prolifera;* (*a*) frond, × 1, and (*b*) small fragment enlarged, × 6. (After Hall and Simpson.)

LXXXVIII. Prismopora Hall.

Ramose, of triangular bifurcating or trifurcating branches, sometimes anastomosing and forming clumps; faces subequal, usually slightly concave, edges sharp, serrated, or wavy; the zoœcia arising from mesothecæ which radiate from center to margins; apertures sometimes on summit of small papillæ; interzoœcial spaces vesiculate, often solid on the surface. Dev.–Carb.

152. **P. triquetra** Hall. Devonic.

Faces of branches from 3 to 6 mm. wide, concave, the apertures in diagonal transverse rows from center of face; peristomes prominent posteriorly; relatively wide non-celluliferous margins; bifurcating branches frequent.

Hamilton of Falls of the Ohio.

LXXXIX. Scalaripora Hall.

Like *Prismopora*, but with faces of triangular branches crossed by salient transverse ridges. Dev.

153. **S. scalariformis** Hall. Devonic.

Faces of branches 3.5 to 4 mm. wide, ray concave, the transverse ridges at intervals of 1.5 mm. and having a height at center of face of 1 mm.; celluliferous; apertures circular, with pronounced peristomes, irregularly disposed.

Hamilton, Falls of the Ohio.

XC. Glyptopora Ulrich.

A thin expansion, with salient ridges or crests on both surfaces, uniting into cup-shaped cavities; ridges sometimes pronounced and reef-like, composed of two layers of zoœcia arising from a mesotheca; upper surface with solid maculæ or dimples. Miss.

154. **G. sagenella** (Prout). (Fig. 214, *e*.) Mississippian.

Cups elongate, often groove- or channel-like; summit of ridges

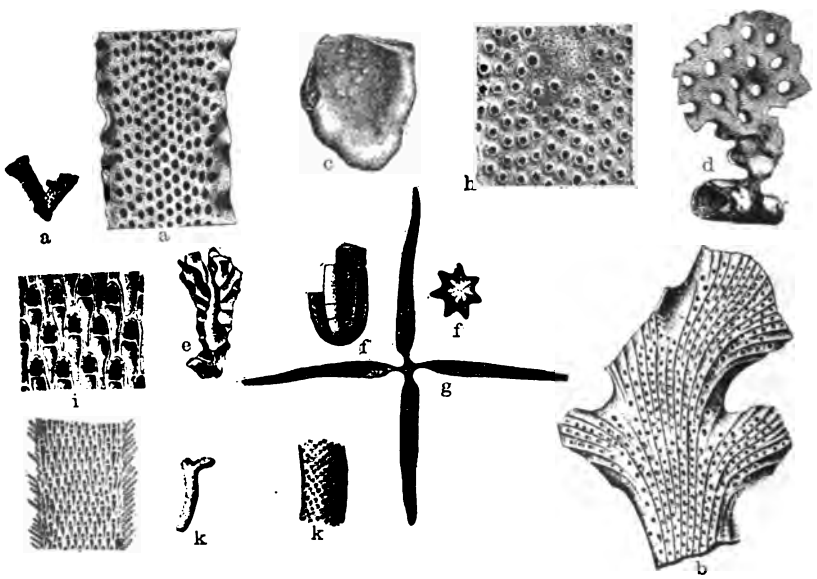


FIG. 214. *a*, *Pachydictya fimbriata*, × ½ and × 4½; *b*, *Cystodictya gilberti*, × 3; *c*, *Dichotrypa lyroides*, fragment showing base, × ½; *d*, *Coscinium latum*, × ½; *e*, *Glyptopora sagenella*, × ½; *f*, *Evactinopora radiata*, basal and lateral views, × ½; *g*, *E. grandis*, × ½; *h*, *Actinotrypa peculiaris*, surface, × 4½; *i*, *Worthenopora spinosa*, fragment showing spines, × 4½, and portion of same enlarged, × 14; *k*, *Stictotrypa punctipora*, × ½, and fragment, × 2. (After Ulrich and Hall.)

sharp, non-poriferous; apertures subcircular, with unequal peristomes.

Keokuk of Iowa; Warsaw of Illinois.

155. **G. (Phractopora) megastoma** (Ulrich). Mississippian.

Cups large; apertures large, subcircular, most pronounced at angles of cups; maculæ conspicuous often on broad elevations; apertures larger near maculæ; generally only fragments of cups found.

Keokuk of Illinois and Iowa; Waverly of Ohio.

XCI. EVACTINOPORA Meek and Worthen.

Free, of four or more vertical leaves of cruciform or stellate arrangement; rays united, thick and nonporiferous in basal portion, free, with subcircular apertures on both sides in upper part; vesicular interspaces, solid at surface. Miss.

156. **E. grandis** Meek and Worthen. (Fig. 214, *g.*) Mississippian.

Large, transverse diameter probably 7 inches; rays 4; apertures small, regularly arranged in quincunx order, separated by about twice their width.

Burlington of Iowa and Illinois.

157. **E. radiata** Meek and Worthen. (Fig. 214, *f.*) Mississippian.

Rounded below, above of eight solid subcarinate rays, with circular pores on thin portions of rays; greatest diameter, from tip to tip of rays, 22.5 mm.

Keokuk of Missouri and Kentucky.

XCII. ACTINOTRYPA Ulrich.

A thin, bifoliate expansion, with 8 to 10 vertical, septa-like ridges in aperture, extending along sides of vestibule. Miss.

158. **A. peculiaris** (Rominger). (Fig. 214, *h.*) Mississippian.

Apertures regularly arranged in diagonal intersecting series, floriform from tooth-like projection of pseudo-septa; peristomes raised; minutely punctured or granular subcircular maculæ characterize the surface at variable intervals.

Keokuk of Missouri, Iowa and Illinois.

XCIII. WORTHENOPORA Ulrich.

Bifoliate, branching or palmate, with regularly arranged elongate rhomboidal zoœcia with semi-elliptical apertures, the trun-

cated posterior margin somewhat raised; line of junction between zoœcia marked by ridge; plain, elongate triangular space below aperture. Miss.

159. **W. spinosa** Ulrich. (Fig. 214, *i.*) Mississippian.

Elongate branches 3 or 4 mm. wide, 0.5 to 0.8 mm. thick; acutely elliptical in section; margins subparallel, with a series of slender spines, pointing obliquely upward.

Keokuk of Illinois and Iowa.

XCIV. LICHENALIA Hall.

Subcircular, unilaminar expansion, with prostrate, elongate subrhomboidal zoœcia, having direct subtubular vestibules and rounded apertures with peristome much elevated on posterior side. Sil.

160. **L. concentrica** Hall. (Fig. 215.) Siluric.

Cup-form in young, flattened at maturity, and variously contorted from irregular growth or accident; concentrically striate and rugose

FIG. 215. *Lichenalia concentrica*, with enlargement of fragment. (After Hall.)

surface on non-celluliferous side; apertures in concentric lines, opening on summit of elevated pustules.

Niagara of New York, etc.

XCV. DIAMESOPORA Hall.

Ramose, of hollow stems, lined internally by an epitheca; simple hexagonal or rhomboidal zoœcia with oval orifices in anterior half

forming with growth tubular vestibules, separated by compact or horizontally laminated interspaces; peristomes equally elevated, or highest posteriorly. Siluric.

161. **D. dichotoma** Hall. (Figs. 216, *a*, 216, *b*.) Siluric.

Regularly bifurcating, generally filled with rock matrix, or crushed; interior of hollow branches, transversely striated, apertures in regularly ascending spiral lines, strongly elevated posteriorly.

Niagara (Rochester) of New York, etc.

FIG. 216, *a*. *Diamelopora dichotoma* enlarged showing oblique peristomes.

XCVI. STICTOTRYPA Ulrich.

Ramose, not pointed at the base; branches dichotomously dividing, narrow, compressed, with circular or elliptical apertures, evenly elevated peristomes, and flat or concave interspaces of horizontally laminated solid tissue. Sil.

162. **S. punctipora** Hall. (Fig. 214, *k*.) Siluric.

FIG. 216, *b*. *Diamesopera dichotoma*, natural size, showing axial hollow.

Flattened, bifurcating; apertures minute, punctiform with elevated peristomes arranged in diagonal series.

Niagara (Rochester) of New York, etc.

XCVII. PALESCHARA Hall.

Thin incrustations with short, direct, generally thin-walled zoœcia, with long, hexagonal or polygonal apertures. Ord.–Dev.

163. **P. incrustans** Hall. Lower Devonic.

On shells (*Spirifer perlamellosus*) or other bodies; 0.1 to 1.0 mm. thick; cells polygonal in contact; walls thick, sometimes with obtuse spinose processes at the angles.

Helderbergian of New York, etc.

MESOZOIC AND CENOZOIC SPECIES.

ORDER CYCLOSTOMATA.

XCVIII. FILIFASCIGERA d'Orbigny.

Irregularly branching, repent zoaria, with apertures in clusters of from two to five or more. Cret.–Tert.

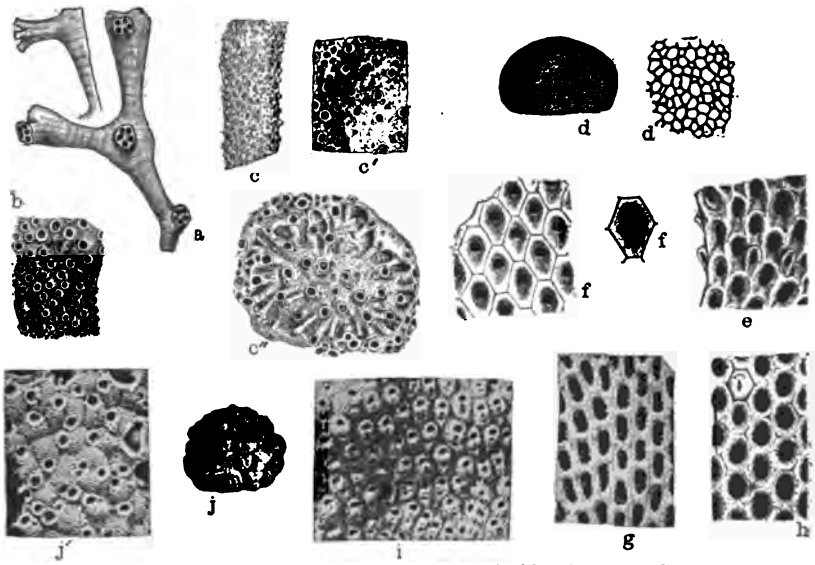


FIG. 217. *a*, *Filifascigera megæra*, × 9, top and side views; *b*, *Discosparsa varians*, surface, × 6; *c*, *Cavaria dumosa*, portion of branch, × 4½; *c'*, fragment showing gonocyst, × 10; *c''*, broken gonocyst to show tubes, × 20; *d*, *Ceriopora micropora*, complete mass, × 3, and surface, × 10; *e*, *Biflustra torta*, surface, × 10; *f*, *Onychocella digitata*, surface, × 10; and single zoœcium showing lunarium-like process, × 15; *g*, *Membranipora oblongula*, surface, × 10; *h*, *M. bimulata*, surface of small-celled variety, × 10; *i*, *Adeonellopsis umbilicata*, surface, × 8; *j*, *Schizoporella informata*, entire mass, × ½; *j'*, surface of same, × 8. (After Ulrich and Md. Geol. Surv.)

164. **F. megæra** Lonsdale. (Fig. 217, *a*.) Cretacic.

Minute, encrusting, with attached portion flattened, clusters of tubes rising at nearly right angles from attached part.

Rancocas formation of New Jersey.

XCIX. DISCOSPARSA d'Orbigny.

Like *Berenicea*, but the obconical or cup-shaped zoœcia attached by center of base only. Cret.–Tert.

165. **D. varians** Ulrich. (Fig. 217, *b*.) Cretacic-Eocenic.

Apertures more or less radially arranged about small depressed, smooth maculæ; ringlike peristomes; interspaces solid.

Common in Upper Cretacic (Rancocas) at Vincentown, N. J., and in the Aquia formation of Maryland.

C. CAVARIA Hagenew.

Ramose, with cylindrical branches, the hollow axis divided by a number of plates; apertures all around the stem, immersed and with prominent peristomes. Gonocysts present.

166. **C. dumosa** Urich. (Fig. 217, *c.*) Eocenic.

A bushy mass of frequently and irregularly dividing and coalescing branches 1.5 to 3.0 mm. thick; surface with maculæ slightly depressed, smooth or with mesopores; gonocysts large rounded or irregular inflations; axial hollow 0.2 to 0.4 mm., with partitions incomplete.

Aquia formation of Maryland.

CI. CERIOPORA Goldfuss.

Encrusting, massive, lobate, or ramose often in two or more superposed layers of tubes; tubes, of one kind, subequal, in close contact with amalgamated porous walls; apertures round or polygonal over entire upper surface.

Abundant in Alpine Trias, less so in Jura, common in Cretacic; Tert.

167. **C. micropora** Goldfuss. (Fig. 217, *d.*) Eocenic.

Depressed globular, hollow beneath; apertures polygonal variable in size.

Nanjemoy formation of Maryland.

CII. HETEROPORA Blainville.

Generally ramose, sometimes of several layers of tubes; apertures rounded, with raised peristomes; mesopores numerous, angular, usually completely surrounding the zoœcia or in clusters, their orifices closed in perfect specimens. Structure as in Ceriopora. Jura–Cret., abundant and Tert.–Recent rare.

168. **H. parvicella** Gabb and Horn. Cret.–Miocenic.

Branches round, irregular, often anastomosing, of several layers of cellules; apertures subregularly disposed with numerous round mesopores, and marked peristomes.

Upper Cretacic of New Jersey.

169. **H. tortilis** Lonsdale. Miocenic.

Apertures placed irregularly, with large irregular angular mesopores and thin walls.

Miocenic of Virginia and South Carolina.

ORDER CHILOSTOMATA Busk.

CIII. BIFLUSTRA d'Orbigny.

Colony lamellose or ramose, cellules on sides in longitudinal series, with slightly elevated peristomes, the anterior position partly

membranous; the two layers of cells separate readily along the median line. Cret.–Recent.

170. **B. torta** Gabb and Horn. (Fig. 217, *e.*) Cret.–Tert.

Small, of compressed branches, usually twisted; cellules in longitudinal lines, usually in quincunx; close together; aperture oval, about half of the cell surface, without lips or peristomes; colony increase in width by interpolation of new rows of cells.

Rancocas of New Jersey and Aquia of Maryland.

CIV. ONYCHOCELLA Waters.

Encrusting or erect, branches compressed, zoœcia hexagonal with raised margins (unless worn), oral openings semilunar or crescentic; scattered avicularian openings in pearshaped areas. Cret.–Recent.

171. **O. digitata** Morton. (Fig. 217, *f.*) Cret.–Tert.

Branches compressed, acutely elliptical, bifurcating, somewhat twisted, 2.5–3.0 mm. wide. Zoœcia bounded by a slightly impressed line, apertures in front of center. Small subcircular cells (avicularia) on margins and below bifurcation.

Upper Cretacic (Rancocas) of New Jersey, Aquia of Maryland.

CV. MEMBRANIPORA Blainv.

Encrusting, irregular calcareous or subcalcareous expansions; zoœcia irregularly arranged or in rows, with variously shaped apertures according to the degree of calcification of the front wall of the zoœcium. Cret.–Recent.

172. **M. plebeia** Gabb and Horn. Cretacic.

Encrusting, sometimes on *O. digitata*, cells generally in radiating lines, elongate to pyriform, separated by depressed lines; apertures large; oral openings occupying the whole cellule.

Rancocas of New Jersey.

173. **M. abortiva** Gabb and Horn. Cretacic.

Cells elongate pyriform to suboval, irregularly arranged; aperture occupying about half the cellule, nearly terminal often acuminate in front and wide behind.

Common in the Upper Cretacic of Timber Creek, and near Mullica Hill, N. J.

174. **M. oblongula** Ulrich. (Fig. 217, *g.*) Miocenic.

Zoœcial apertures in longitudinal series elongate ovate to subquadrate, about twice as long as wide, occupying entire cellule;

walls generally thick, with numerous thin spines projecting inward from them.

Choptank and Calvert formation of Maryland.

175. **M. bimulata** Ulrich. (Fig. 217, *h.*) Eocenic.

Zoœcia hexagonal, arranged quincuncially with longitudinal rows generally regular; apertures occupying entire cell, quite regularly ovate in form; interapertural space narrowed and rounded, sometimes angular, often with depressed central line.

Aquia formation of Maryland.

CVI. Adeonellopsis Macgillivray.

Encrusting with bulbous cells having subcircular to semicircular opening, beneath which is a second circular or crescentic pore. Cret.–Tert.

176. **A. umbilicata** (Lonsdale). (Fig. 217, *i.*) Miocenic.

Irregular nodose masses of numerous layers; zoœcia irregular, central and anterior portion elevated and outline of each marked by a row of pores; upper front wall coarsely punctate; orifice anterior, semielliptical, 2 smaller apertures on the proximal portion of the cell.

Chesapeake Group of Virginia and Choptank formation of Maryland. Common.

CVII. Schizoporella Hincks.

Zoaria variable; zoœcia urn-shaped, the front entirely calcified; orifice varying from semicircular to suborbicular, with a distinct notch or sinus in the lower margin. Cret.–Recent.

177. **S. informata** (Lonsdale). (Fig. 217, *j.*) Miocenic.

Irregular botryoidal or nodulose masses of superposed layers of zoœcia, 20 to 40 mm. in diameter; cells with terminal subcircular orifice with distinct peristome and deep and sharp proximal notch; entire surface punctate; avicularia uncommon.

Chesapeake group of Virginia and Choptank formation (?) of Maryland.

Class **Brachiopoda.**

Brachiopods are marine animals secreting a shell of two pieces or valves which may be calcareous or phosphatic or both. These valves are dorsal and ventral in position and are usually of unequal size, a larger, the *pedicle* or *ventral valve* and a smaller, the *brachial*

or *dorsal*. They are usually attached to some foreign object, such as rocks, etc., by a fleshy stalk, the *pedicle* (Fig. 219, 5); this posterior prolongation of the animal's body passes through an opening, the *delthyrium*, or the more restricted *foramen* at the posterior end of the pedicle valve. The shell is sometimes anchored by spines and sometimes it is cemented to its support (*Crania*).

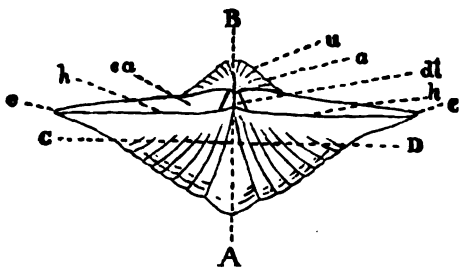


FIG. 218. Diagram of *Spirifer*. (*AB*) longitudinal axis marking the height; (*CD*) transverse axis marking the width; (*A*) anterior (front) end; (*B*) posterior (beak) end; (*h*) hinge line; (*ca*) cardinal area; (*e*) cardinal extremities; (*dt*) delthyrium; (*u*) umbo; (*a*) apex or beak.

The interior of the shell is lined by the mantle, a membranous reduplication of the body wall, which is often studded with minute cæca or blind tubes which enter the perforations (tubules) of the shell, thus giving the shell a punctate structure. The pedicle valve is secreted by the ventral and the brachial valve by the dorsal mantle lobe. In the Protremata the dorsal surface of the pedicle secretes a third shellpiece, the *deltidium*, or pedicle plate, which unites with the posterior margin of the pedicle valve and continues to grow anteriorly (*Schuchertella*, Fig. 276). In the Telotremata, where this deltidium is absent, the extension of the ventral mantle lobe effects the protection of that portion of the pedicle by a secretion of two plates, the deltidial plates or *deltaria* which may unite to form the *pseudodeltidium*. In some of the Neotremata (*Orbiculoidea*, etc.), a single plate, the *listrium*, forms between the apex of the pedicle valve and the opening for the pedicle. In some forms (*Spirifer*) the delthyrium is filled by the deposition within the shell of solid calcareous material. In extreme cases a tubular sheath, the *syrinx*, is formed on this calcareous filling (*Syringothyris*) (Fig. 436).

Externally the shell is marked with concentric lines (*growth lines*) which represent the successive stages of growth; as the shell grows a new layer is added to the inside, projecting beyond the preceding layer, thus forming a "series of outcrops." These growth

lines are more or less conspicuous. Besides this ornamentation, shells frequently bear folds or *plications* radiating from the region of the beak to the anterior portion of the valves (*Spirifer*, Fig. 218, *Magellania*, Fig. 219, 4–5). When these are fine they are generally spoken of as *striations*. Frequently the striæ alternate in size. They may increase by intercalation or implantation of new ones between the diverging older ones, or these latter may bifurcate. (See Figs. 251 to 275 for variations). Frequently the median line of the brachial valve bears a much larger fold called the *median fold*, while the corresponding large depression on the pedicle valve is called the *median sinus* (*Spirifer*, Fig. 409). In some forms the sinus and fold are reversed in position (*Anastrophia*, *Gypidula*, *Enteletes*, etc.), while in others they are entirely wanting (*Whitfieldella*).

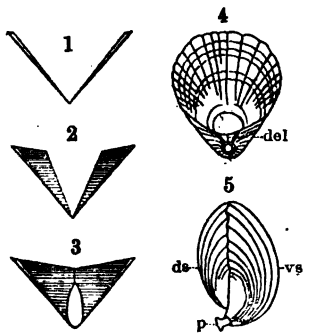


FIG. 219. 1, Delthyrium of young *Rhynchonella* without deltidial plates; 2, the same at a later stage with two triangular deltidial plates; 3, the same after completed growth; showing joining of deltidial plates, and limitation of pedicle opening to ventral beak (foramen); 4, dorsal view of *Magellania flavescens*, showing completed deltidial plates *del*; 5, profile of same; *vs*, ventral (pedicle) valve; *ds*, dorsal (brachial) valve; *p*, pedicle. (After Beecher).

The *length* or *height* of the shell is the distance from the hinge line, or line of junction of the valves, through the middle of the shell to the opposite edge or front (*A–B* in Fig. 218). The *width* is in the direction at right angles to this or on a line extending from side to side of the shell (*C–D* in Fig. 218). The *thickness* is in the direction perpendicular to the plane of length and width through the center of the valves.

There is usually a flattened area at the posterior portion of each valve between the *beak* (*a*) and the *hinge line* (*h*) and extending to the *cardinal angles;* this is the *cardinal area* (*ca* in Fig. 218). The cardinal area of the pedicle valve is the higher.

In the Articulata a pair of *teeth* on the posterior portion of the pedicle valve fit into corresponding *sockets* on the brachial valve Fitting between the teeth of the pedicle valve is a short prolongation of the brachial valve, the *cardinal process* (Fig. 261). Teeth and sockets are usually absent in the Inarticulata. The dental sockets are

bounded on the inside by *hinge plates* which are united above with the cardinal process. Similar plates, the *dental plates*, bound the inner side of the teeth; at times these unite before reaching the bottom of the shell, thus forming a plate or cup upon which are fastened the diductor, adductor and pedicle muscles. This cup is called the *spondylium* (*Gypidula*). In some genera (*Merista*, etc.) a free plate, of different origin, the *shoe-lifter process*, occurs in place of the spondylium. The solid or excavated platforms in some of the Atremata (*Trimerella*, Fig. 226) are homologous to the spondylium. A corresponding structure sometimes occurs in the brachial valve where it is known as the *cruralium*. The muscle areas are more deeply impressed upon the posterior portion of each valve. This area in each valve is frequently divided into halves by a vertical plate or *septum* extending from beneath the beak anteriorly, never reaching the front of the shell (Fig. 233, *s*).

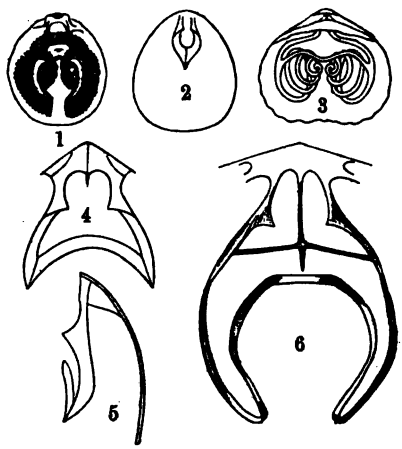


FIG. 220. 1, Dorsal valve of *Terebratulina septentrionalis* with cirrated brachia attached; showing relation of calcareous loop which is darkly shaded; 2, Centronelliform stage of loop of *Dielasma turgidum* × 6; 3, spirals and loop in *Zygospira modesta* × 2½; 4, loop and crural plates of adult *Dielasma turgidum* × 4; 5, side view of same × 4; 6, adult loop of *Terebratalia obsoleta*. (After Beecher, and Beecher and Schuchert).

Curving forward from the posterior portion of the brachial valve or from the cruralium there is a pair of short processes, the *crura*; to these in many shells are united more or less complicated calcareous ribbons, the *brachidia* (Fig. 218, 2–6). When spirally coiled as in *Spirifer* or *Zygospira* they are called *spiralia* (Fig. 220–3).

The valves are opened and closed by muscular action. The pedicle valve is held stationary by means of the pedicle. Through the contraction of two pairs of muscles (*diductors* or *divaricators*) extending from the posterior portion of the pedicle valve to the cardinal process on the opposite valve the shell opens, since the cardinal process by its position posterior to the teeth forms a sort of lever with the teeth and sockets as fulcrum, and the front of

the brachial valve as weight. The valves close by the contraction of two muscles (*adductors*) passing from the brachial to the pedicle valve. A pair of muscles extending from the brachial valve and another pair from the pedicle valve with insertion on the pedicle, enable the shell as a whole to move in many different directions. In the Inarticulata the opening and closing of the valves is effected by a more complicated set of muscles. (See *Lingula*, Fig. 221.)

The body of the animal, lying in the posterior portion of the shell, occupies only about one third of the interior. The body wall gives off two folds or mantles, one fitting closely to and building the pedicle valve, the other building the brachial valve. Most of the space between the mantles is filled with the tentacle-bearing *lophophore* (Fig. 220, 1); this is supported by the brachidium. Those portions of the lophophore which diverge arm-like from the two sides of the mouth are called the *brachia*. Through this lophophore and tentacles as well as through the mantle the animal gets its necessary oxygen. There is also a cilia-lined groove, which is bounded on the outside by the line of tentacles and on the inner side by a wavy ridge, and which extends from the mouth along each arm of the lophophore. Through this, microscopic food particles (diatoms, infusorians, etc.) are swept into the mouth by the action of the cilia. The *mouth*, a mere slit, is in the middle of the lophophore; it leads into a *stomach* through an *œsophagus*. The stomach leads into an *intestine*, which often ends as a blind sac.

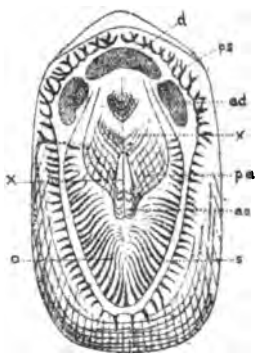


FIG. 221. *Lingula elderi*, outline of interior of dorsal valve showing muscular and vascular markings; *d*, divaricator muscular scars; *ad*, adjustor muscular scars; *pa*, posterior adductor scars; *aa*, anterior adductor scars; *xx*, track of advance of the muscular scars; *s*, great pallial sinuses; *ps*, posterior course of the latter; *o*, inner ramifications of the sinuses. (After Whitfield.)

The body cavity or coelome extends into the lophophore and also sends off four canals (*pallial sinuses*) into each mantle; the outer ones are much branched. Impressions of these pallial sinuses are often found on the inside of the shell and on internal molds (Fig. 221, *s*).

The function of the blood is performed mainly by the fluid filling the coelome and moved by the cilia lining it. A contractile heart and some vessels leading from it have been observed.

The nervous system consists of a ring around the œsophagus with two swellings or ganglia in it; nerves are given off to the rest of the body.

It is apparent that the pedicle valve is so called because the pedicle passes out through it and the brachial valve is so named because the arms or brachia are fastened to it.

Brachiopods are, in the larval stage, free-floating or meroplanktonic, and hence it is during this period of their lives that their distribution takes place.

Brachiopods appear in the Lower Cambric; they reach their maximum in the Siluric and Devonic and continue to the present. There are about 6,000 fossil species known and 140 recent.

These shells often appear very similar to Pelecypods but may be distinguished from them by the following characters, which as a rule hold true:

Brachiopods.	Pelecypods.
Equilateral.	Inequilateral.
Inequivalved.	Equivalved (generally).
Pedicle opening present (except in *Atremata*).	No pedicle opening present.
Teeth in one valve, sockets in the opposite valve (except *Inarticulata*).	Teeth and sockets in each valve (typically).
No ligament present; valves opened by muscles.	Valves opened by ligament or resilium at hinge line.

Brachiopods are divided according to the presence or absence of teeth into two subclasses:

I. *Inarticulata* — Teeth absent. Valves held in apposition by muscles. This is subdivided into two orders:

1. Atremata — Pedicle emerging from between the valves and usually with no pedicle opening present.

2. Neotremata — Pedicle opening confined to pedicle valve and modified by false deltidium or by listrium.

II. *Articulata* — Valves articulated by teeth and sockets. This is subdivided into two orders:

1. Protremata — Pedicle opening restricted to pedicle valve and modified by true deltidium. Brachia have no calcareous supports except very short ones in *Pentamerus*.

2. Telotremata — Pedicle opening shared by both valves in early life and usually confined to one in later stages. Brachia supported by calcareous supports. Deltidial plates usually present.

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ARTIFICIAL KEY TO THE GENERA.

A. Beak not marginal..... I.
I. Shell cemented, calcareous, with no pedicle opening or notch (rarely free).. 1.
1. Interior of each valve with a large, elevated muscular impression.
XXV. *Pholidops.*
1. Interior of each valve with three or four muscular impressions..... *a.*
a. An S-shaped vascular sinus present..... XXIV. *Craniella.*
a. No S-shaped vascular sinus present..... XXIII. *Crania.*
I. Shell attached by pedicle, phosphatic; pedicle opening or notch present..... 2.
2. Pedicle opening a narrow groove, not extending to the margin of the shell. *b.*
b. Pedicle groove very narrow, extending almost to the margin of the shell..... XIX. *Orbiculoidea.*
b. Pedicle groove suboval, extending about half way from the beak to the margin of the valve..... ..... 11.
11. Both valves convex, the pedicle the more so.. XXI. *Schizotreta.*
11. Brachial valve very convex; pedicle valve concave..... *aa.*
aa. Pedicle opening surrounded by a depressed area.
XX. *Discinisca.*
aa. Pedicle opening not surrounded by a depressed area.
XXII. *Rœmerella.*
2. Pedicle opening round, abruptly truncating the apex ..... *c.*
c. Shell depressed-convex; beak elevated..... XII. *Acrothele.*
c. Shell sub-conical ..... 22.
22. Pedicle valve with an apparent cardinal area ..... *bb.*
bb. Two wart-like protuberances on the umbo.. XI. *Acrotreta.*
bb. No wart-like protuberances on the umbo... XIV. *Iphidea.*
22. Pedicle valve without apparent cardinal area.
XIII. *Linnarssonia.*
2. Pedicle opening a triangular notch.....*d.*
d. Surface with prominent radiating pits..... XV. *Trematis.*
d. Surface without radiating pits ..... 33.
33. Brachial valve extending beyond the pedicle valve on all sides. *cc.*
cc. Surface with radiating striæ ..... XVI. *Schizocrania.*
cc. Surface without radiating striæ..... XVII. *Lingulodiscina.*
33. Brachial valve not extending beyond the pedicle valve.
XVIII. *Schizobolus.*
B. Beak marginal ..... II.
II. Cardinal area absent or if present rarely straight and generally confined to pedicle valve; hinged line curved or if straight very short 3
3. Shell obolelloid — Small, thick-shelled, ovate in outline. Cardinal areas very short..... *e.*
e. Shell calcareo-corneous..... II. *Dicellomus.*
e. Shell calcareous..... 44.
44. Umbo very conspicuous..... XXVI. *Kutorgina*
44. Umbo not conspicuous.....I. *Obolella.*
3. Shell trimerelloid — Large, thick-shelled. Cardinal area of pedicle valve very high; beak straight and very prominent. Beak of brachial valve inconspicuous. Interior of each valve has a conspicuous platform extending from the beaks forward..... *f.*

f. Platforms very prominent with conical cavities beneath.....55.

55. Conical cavities very long, extending from one third to one half the length of the shell as shown by the internal molds. V. *Trimerella.*

55. Conical cavities short, extending about one tenth the length of the shell..... III. *Dinobolus.*

f. Platforms not very prominent, solid (*i. e.*, with no cavities beneath them)..... IV. *Monomorella.*

3. Shell linguloid — Elongate, corneous, thin (except *Lingulasma*)..... *g.*

g. Inequivalved (pedicle valve the larger, projecting posteriorly), spatulate..... 66.

66. Cardinal area distinct..... *dd.*

dd. Shell minute (about $\frac{1}{12}$ inch long).* VIII. *Leptobolus.*

dd. Shell larger ($\frac{1}{4}$ to $\frac{3}{4}$ inch long) with high cardinal area. VI. *Lingulella.*

66. Cardinal area not distinct; pedicle valve often much produced at beak.....VII. *Lingulepis.*

g. Equivalved. Surface glistening..... 77.

77. Platform present in the posterior portion of each valve. X. *Lingulasma.*

77. No platform present..... IX. *Lingula.*

3. Shell pentameroid — Usually longer than wide and expanding in width from beak to front. Beak generally incurved, not truncated by foramen, rarely with area. Sinus and fold variable. A spondylium in pedicle valve..... *h.*

h. No radiating striæ or plications..... 88.

88. Sinus or fold present..... *ee.*

ee. Small (average length $\frac{1}{8}$ inch).....LXII. *Camarella.*

ee. Not so small..... †.

† Umbo of pedicle valve very prominent and overarching *.

* Sinus in pedicle valve and fold in brachial. LXVIII. *Clorinda.*

* Sinus, when present, in brachial valve and fold in pedicle..... LXX. *Gypidula.*

† Umbo of pedicle valve small..... LXVII. *Pentamerus.*

88. Sinus or fold absent..... *ff.*

ff. Umbo of pedicle valve prominent..... LXX. *Gypidula.*

ff. Umbo small..... LXVII. *Pentamerus.*

h. With radiating striæ or plications, without area..... 99.

99. Sinus or fold present..... *gg.*

gg. Striæ or plications absent from umbo..... ††.

†† Small (average length $\frac{1}{8}$ inch)..... LXII. *Camarella.*

†† Large..... **.

** Umbo of pedicle valve large..... LXX. *Gypidula.*

** Umbo comparatively small..... ..... 1″.

1″ Shell outline subcircular. LXIII. *Parastrophia.*

1″ Shell outline subtriangular. LXXII. *Camarophoria.*

* All measurements refer to adults.

gg. Striæ or plications extending from umbo to front of shell. †††.
††† Pedicle valve the larger with more prominent umbo. ***.
*** Radiating plications very few and broad..... 2″.
2″ Umbo of pedicle valve strongly overarching.
LXVIII. *Clorinda*.
2″ Umbo not overarching.
LXVII. *Pentamerus*.
*** Radiating plications numerous and prominent. 3″.
3″ Spondylium only in pedicle valve.
LXXII. *Camarophoria*.
3″ Spondylium in pedicle and brachial valve (cruralium)..... *a″*.
a″ Umbo of pedicle valve closely incurved against the brachial.
LXVIII. *Clorinda*.
a″ Umbo of pedicle valve projecting above the brachial..... 1‴.
1‴ Sinus, when present, on brachial valve and fold on pedicle.
LXX. *Gypidula*.
1‴ Sinus on pedicle valve and fold on brachial.. LXIX. *Pentamerella*.
††† Brachial valve the larger. Both umbos very closely incurved, that of the brachial valve the more prominent..... LXIV. *Anastrophia*.
99. Sinus or fold absent..... *hh*.
hh. Shell with radiating plications ..... ††††.
†††† Plications few and broad..... LXVII. *Pentamerus*.
†††† Plications numerous..... ****
**** Plications angular ..... LXXII. *Camarophoria*.
**** Plications round..... 4″.
4″ Spondylium in pedicle valve.
LXV. *Conchidium*.
4″ Spondylium in both pedicle and brachial valves..... LXX. *Gypidula*.
hh. Shell with radiating striæ, very fine plications or smooth. 5†.
5† Pedicle valve with a spondylium. LXXI. *Amphigenia*.
5† Pedicle valve without a spondylium.
LXXXVIII. *Rensselæria*.
Shell with small area and with radiating striae or plications..... ooo.
ooo. Area on both valves, nearly equivalve. LXVI. *Stricklandinia*.
ooo. Area on pedicle valve, which is the larger and has overarching umbo..... *ii*.
ii. Sinus on brachial and fold on pedicle..... LXX. *Gypidula*.
ii. Sinus on pedicle and fold on brachial valve.
LXIX. *Pentamerella*.
3. Shell rhynchonelloid — Length and breadth sub-equal. Cardinal areas rarely present. Umbo not prominent, becoming abruptly pointed (*i. e.*, forming a concave line from beak to greatest width of shell). Beak usually closely incurved, generally not truncated by foramen.

Sinus and fold prominent, in typical forms surface with plicæ generally coarse..... *i.*

i. Fold and sinus absent..... 111.

111. Large, with false area, no spondylium. LXXXV *Peregrinella.*

111. Small, with spondylium..... .....LXXII *Camarophoria.*

i. Fold and sinus present..... 222.

222. Plications moderately developed on the lateral slopes or wanting, prominent centrally and anteriorly, no spondylium..... *jj.*

jj. Sinus exceedingly prominent..... LXXXII. *Pugnax.*

jj. Sinus moderately prominent..... LXXVIII. *Leiorhynchus.*

222. Plications absent from the umbo, sponydium well developed. *kk.*

kk. Plications roughened by strong concentric growth lines. LXXII. *Camarophoria.*

kk. Plications smooth..... .... 6†.

6† Shell very small (about ¼ inch long). LXII. *Camarella.*

6† Shell moderately large..... LXIII. *Parastrophia.*

222. Entire shell covered with plications or striations..... *ll.*

ll. Both umbos very prominent, that of the brachial valve the more conspicuous, well marked spondylium in pedicle valve.....LXIV. *Anastrophia.*

ll. Umbo of pedicle valve the more prominent..... 7†.

7† Pedicle umbo very closely incurved over the brachial. 5*.

5* Plications marked anteriorly by a faint median line. Shells ventricose, no spondylium..... 5′′.

5′′ Median septum and cardinal process in brachial valve well developed. LXXIX. *Uncinulus.*

5′′ Cardinal process absent... LXXX *Wilsonia.*

5′′ Median septum in brachial valve very faint. LXXXI. *Hypothyris.*

5* Plications not marked anteriorly by a median line. 6′′.

6′′ Pedicle valve with obscure muscular scars and well-marked spondylium. LXXII. *Camarophoria.*

6′′ Pedicle valve with prominent muscular scars without spondylium..... *b′′.*

b′′ Brachial valve with median septum. 2′′′.

2′′′. Septum excavated posteriorly; teeth supported by lamellæ; no cardinal process. LXXVI. *Camarotœchia.*

2′′′. Septum not excavated; strong recurved teeth without lamella; slender cardinal process. LXXIV. *Rhynchotrema.*

b′′. Brachial valve without median septum. LXXVII. *Stenochisma.*

7† Pedicle umbo projecting, not very closely incurved over the brachial, commonly showing deltidial plates and foramen..... 6*.

6* Hinge line straight with flattened margins .....7''.
7'' Pedicle valve prolonged posteriorly and acutely triangular, flattening from large deltarium..... LXXV. *Rhynchotreta.*
7'' Pedicle valve not prolonged posteriorly ; flattening a cardinal area in each valve.
LXXIII. *Orthorhynchula.*
6* Hinge line curved, no flattening..... 8''.
8'' Pedicle valve with deeply excavated muscular scars, sinus forming nasute anterior prolongation.....LXXXIII. *Eatonia.*
8'' Pedicle valve with muscular scars not deeply excavated..... *c''.*
c'' Shell structure punctate.
LXXXIV. *Rhynchopora.*
c'' Shell structure not punctate..... 3'''.
3''' Pedicle valve with pseudo area and strong teeth supported by lamellæ ; brachial valve with septum entire.
LXXXV. *Rhynchonella.*
3''' Small teeth with slender lamellæ, septum of brachial valve excavated posteriorly..... *a'''.*
a''' Plications low and rounded.
LXXVIII. *Leiorhynchus.*
a''' Plications sharp and angular.
LXXVI. *Camarotœchia.*

3 Shell terebratuloid or athyroid — Typically no flat cardinal area. Hinge line curved. Beak incurved, often truncated by foramen. Median sinus and fold often absent ; when present usually broad and ill-defined. Radiating plications or striæ usually absent ; when present they are never angular; arms generally supported by calcareous brachidium. *j.*
j. Shell smooth, calcareous brachidium present..... 333.
333. Median sinus and usually fold present..... *mm.*
mm. Beak of pedicle valve truncated by a round foramen.. 8†.
8† Length and breadth subequal, brachidium a spiralium. 7*.
7* Shell usually small (about ¼ inch long or less).
CXXIII. *Seminula.*
7* Shell of medium size, margins of sinus rounded.
CXXIV. *Meristella.*
7* Shell of medium size, margin of pronounced and broad sinus angulated, fold with median groove.
CXXV. *Pentagonia.*
8† Length greater than breadth, brachidium a simple loop. 8*.
8* Beak of pedicle valve prolonged and greatly incurved over opposite valve. Pedicle opening large..... XC. *Dielasma.*

8* Beak of pedicle valve much less prominent... 9''.
9'' Shell usually plano-convex (pedicle valve convex)..... LXXXVII. *Centronella.*
9'' Shell biconvex; length but slightly greater than breadth..... XC. *Cranæna.*
8† Length greater than breadth, brachidium a spiral. CXV. *Whitfieldella.*
mm. Beak of pedicle valve not truncated by a round foramen; brachidium a spiralium of complex loop..... 9†.
9† Median sinus a mere groove..... CXVII. *Nucleospira.*
9† Median sinus very broad and ill-defined; no fold present..... { CXX.* *Meristina.* / CXXIV.* *Meristella.*
9† Median sinus very broad and pronounced, sides angulated, fold pronounced and with median groove. CXXV. *Pentagonia.*
9† Median sinus and fold both present and of normal width..... 9*
9* Sinus and fold only upon the anterior portion of the shell, spire very short..... XCVIII. *Cyclospira.*
9* Sinus and fold extending from umbo ..... 10''
10'' A broad plication present on each side of median sinus and fold... CXVI *Hyatella.*
10'' No plications present..... CV. *Martinia.*
333. Median sinus and fold absent..... *nm.*
nn. Beak of pedicle valve truncated by a round foramen... 10†.
10† Length and breadth subequal; brachidium a spire.. 10*.
10* Concentric growth lines lamellose..... 11''.
11'' Edges of the lamellæ spinose. CXXII. *Cleiothyris.*
11'' Edges of the lamellæ not spinose. CXXI. *Athyris.*
10* Concentric growth lines few and not lamellose. CXV. *Whitfieldella.*
10† Length greater than breadth or subequal; brachidium a loop..... 11*
11* Umbo comparatively narrow; shell elongate.. 12''.
12'' Concentric growth lines usually well marked. LXXXIX. *Cryptonella.*
12'' Concentric growth lines usually not prominent..... XCI. *Eunella.*
11* Umbo broad; shell elongate.. XCII. *Terebratula.*
11* Umbo broad; shell subcircular.. XCV. *Kingena.*
nn. Beak of pedicle valve not truncated by a foramen..... 11†.
11† Prominent cardinal area present. 380. *Reticularia perplexa.*
11† No cardinal area present..... CXVII. *Nucleospira.*
j. Shell radially plicate or striate; brachidium wanting in some forms... 444.

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* These two genera are separated by the character of the loop.

444. Median sinus and fold present; brachidium when present, a spiralium ..... *oo.*

oo. Beak of pedicle valve truncated by a foramen. Shell transversely elongate; spires extraverted ..... 12†.

12† Plications covered with minute spines.
CXIII. *Parazyga.*

12† Plications without spines.....CXII. *Trematospira.*

oo. Beak of pedicle valve not truncated by a foramen..... 13†.

13† Shell with faint radiating striæ; spirals extraverted.
CXXIV. *Meristella.*

13† Shell radially plicate; spirals absent, or when present not extraverted ..... 12*.

12* Plications confined to anterior portion of shell; spiralium absent.....LXII. *Camarella.*

12* Plications covering whole shell..... 13″.

13″ Sinus on pedicle valve and fold on brachial; spirals pointing into pedicle valve.
CXVIII. *Anoplotheca.*

13″ Sinus on brachial valve and fold on pedicle; spirals pointing inward (introverted).
XCVII. *Zygospira.*

444. Median sinus and fold not present ..... *pp.*

pp. Beak of pedicle valve truncated by a foramen; deltidial plates visible ..... 14†.

14† Shell with faint radiating striæ; brachidium a loop, deltidial plates minute..... XCIII. *Terebratulina.*

14† Shell with coarse plications; brachidium a loop, deltidial plates moderate..... XCVI. *Terebratella.*

14† Shell radially plicate; brachidium of extraverted spires, deltidial plates pronounced, commonly coalesced..... 13*.

13* Plications rather coarse..... CXI. *Hustedia.*

13* Plications fine or striate..... 14″.

14″ Deltidial plates uncoalesced.
CX. *Homœospira.*

14″ Deltidial plates coalesced..... *d‴*.

d‴. Surface plicate..... CIX. *Rhynchospira.*

d‴. Surface striate..... CXIV. *Eumetria.*

pp. Beak of pedicle valve not truncated by a round foramen. 15†.

15† Brachidium a spire turned into the extremely convex brachial valve; plications rounded, low.
XCIX. *Atrypa.*

15† Brachidium a loop..... 14*.

14* Length greater than breadth; plications fine.
LXXXVIII. *Renssellaeria.*

14* Subcircular; plications angular, prominent; small well defined cardinal area and deltidial plates on pedicle valve..... XCVI. *Terebratella.*

II. Cardinal area present, straight. Hinge line straight and long, usually more than one third the greatest width of shell..... 4-

4. Shell strophomenoid—Length and breadth subequal. Hinge line forming usually the greatest width of the shell. Shell usually concavo-convex, never strongly biconvex. Cardinal areas well developed; delthyrium triangular and usually closed (open in *Vitulina*, *Tropidoleptus*, *Syntrophia*, *Scenidium*). Median sinus and fold usually absent; when present very broad and ill-defined. Surface radially striate, seldom plicate or smooth ..... *k*.

k. Surface radially striate..... 555.

555. Margins of hinge line finely grooved transversely..... *qq*.

qq. Shell normally concavo-convex (brachial valve concave, pedicle valve convex)..... XXXII. *Stropheodonta*.

qq. Shell resupinate (brachial valve convex, pedicle valve concave)..... XXXIV. *Strophonella*.

555. Margins of hinge line not transversely grooved..... *rr*

rr. Cardinal margin of pedicle valve with a simple row of spines..... 16†.

16† Shell normally concavo-convex..... 15*.

15* Surface simply striate radially... XLII. *Chonetes*.

15* Surface with a double oblique series of striæ extending from umbo..... XLIV. *Chonopectus*.

16† Shell resupinate..... XLIII. *Chonostrophia*.

rr. Cardinal margins without spines..... 17†.

17† Radiating striæ alternating in height..... 16*.

16* Shell normally concavo-convex..... 15″.

15″ Shell large..... XXXI. *Rafinesquina*.

15″ Shell small..... XXXVII. *Plectambonites*.

16* Shell resupinate..... XXXV. *Strophomena*.

17† Radiating striæ subequal in height..... 17*.

17* Front of shell geniculate (abruptly bent almost at right angles); concentric wrinkles on older portion..... XXXVI. *Leptæna*.

17* Front of shell not geniculate..... 16″.

16″ Radiating striæ prominent, sharp, crowded; umbo apt to be distorted..... *f*″.

e″ Pedicle valve with spondylium. LIX. *Clitambonites*.

e″ Pedicle valve without spondylium... 4‴.

4‴ Muscular area of pedicle valve surrounded by a strong ridge. XLI. *Hipparionyx*.

4‴ Muscular area of pedicle valve not surrounded by a strong ridge. *b*‴.

b‴ High median septum present, running through center of muscular area. XXXIX. *Orthothetes*.

b‴ High median septum not present.. XXXVIII. *Schuchertella*.

16″ Radiating striæ faint..... *f*″.

f″ Shell concavo-convex, resupinate. XXXV. *Strophomena*.

f'' Shell plano- or bi-convex.
XXVIII. *Billingsella.*

k. Surface radially plicate..... 666.
666. Plications coarse, radially striate..... XL. *Meekella.*
666. Plications not radially striate..... *ss.*
ss. Entire surface pustulose. Shell small..... CXIX. *Vitulina.*
ss. Spines irregularly distributed on the crests of the plications.
XXIX. *Nisusia.*
ss. No spines or pustules present..... 18†.
18† Shell distinctly punctate..... 18*.
18* Plications sharp..... XXX. *Protorthis.*
18* Plications rounded..... XCIV. *Tropidoleptus.*
18† Shell not distinctly punctate..... 19*
19* Shell very small, cyrtiniform (cardinal area of pedicle valve very high)..... LX. *Scenidium.*
19* Shell comparatively large.
XXVIII. *Billingsella.*

k. Surface spinose (productoid)..... 777
777. Pedicle umbo prominent and strongly incurved..... *tt.*
tt. Shell small..... XLVI. *Productella.*
tt. Shell large..... XLVII. *Productus.*
777. Pedicle valve not strongly incurved, often truncate.
XLV. *Strophalosia.*

k. Surface smooth except for concentric growth lines..... 888.
888. Margins of hinge area vertically grooved.
XXXIII. *Pholidostrophia.*
888. Margins of hinge area not grooved..... *uu.*
uu. Hinge line short. Umbo usually conspicuous. No spondylium, large delthyrium.....XXVI. *Kutorgina.*
uu. Hinge line long. Umbo inconspicuous; spondylium present.
LXI. *Syntrophia.*

4. Shell orthoid — Shell usually plano- or bi-convex, never definitely concavo-convex. Hinge line usually much less than the greatest width of the shell. Cardinal areas well and almost equally developed in each valve; triangular delthyrium usually well developed in each valve and open. Median sinus when present generally very broad and ill defined. Surface marked with radiating striæ or plications..... *l.*

l. Surface radially plicate (*i. e.*, radiating lines coarse)..... 999
999. Hinge line short, forming about one third the greatest width of the shell. Shell globular..... LVIII. *Enteletes.*
999. Hinge line long..... *vv.*
vv. Pedicle valve flat or partly concave; brachial convex.
L. *Dinorthis.*
vv. Pedicle valve convex..... 19†.
19† Brachial valve flat..... 20*.
20* Deltidium present in pedicle valve..... 17''.
17'' Spines present..... XXIX. *Nisusia.*
17'' Spines absent..... *g''*.
g'' Shell punctate... XXVIII. *Billingsella.*
g'' Shell impunctate..... XXX. *Protorthis.*

20* No deltidium present ..... 18''.
18'' Shell cyrtiniform with erect cardinal area.
LX. *Scenidium.*
18'' Shell not cyrtiniform..... XLVIII. *Orthis.*
19† Brachial valve convex..... 21*
21* Strong mesial fold on brachial valve and corresponding sinus on pedicle valve, both with sharp plications ..... LIII. *Platystrophia.*
21* No mesial fold present. Shallow sinus present or absent..... XLIX. *Plectorthis.*

l. Surface radially striate (*i. e.*, radiating lines fine; except *Hebertella borealis* 174)..... IIII
IIII. Strongly two-lobed. Very small..... LIV. *Bilobites.*
IIII. Not strongly two-lobed..... *ww.*
ww. Hinge line short (about ⅓ the greatest width of shell). 20†.
20† Valves subequal and gently biconvex.
LVI. *Rhipidomella.*
20† Brachial valve very convex. Pedicle valve much less convex..... LVII. *Schizophoria.*
ww. Hinge line long, pedicle valve deep, brachial valve flat or shallow..... 21†
21† Shell substance punctate..... LV. *Dalmanella.*
21† Shell substances impunctate..... 22*
22* Pedicle valve subpyramidal. Deltidium and spondylium present..... LIX. *Clitambonites.*
22* Pedicle valve depressed convex..... 19''.
19'' Muscular impression of pedicle valve small, almost confined between the dental lamellæ ..... LII. *Orthostrophia.*
19'' Muscular impression of pedicle valve moderately large, extending about one half the distance from beak to front.
LI. *Hebertella.*

4. Shell spiriferoid — Usually transversely elongate with hinge line forming greatest width of shell. Bi-convex, very seldom plano-convex. Cardinal area with the open triangular delthyrium most conspicuous on the pedicle valve rarely with pseudodeltidium. Median sinus on pedicle valve and fold on brachial (reversed in *Metaplasia*, *Vitulina*, *Scenidium*). Shell usually radially plicate, rarely smooth or striate. Brachidium typically an extraverted spire..... *m.*

m. Conspicuous spines present.
CIV. *Reticularia* (except *R. nevadæensis*, *R. lævis* and *R. perplexa*).
m. Minute spines present..... 324. *Spiriferina spinosa.*
m. Spines absent or microscopic ..... 2222.
2222. Surface lacking plications..... *xx.*
xx. Mesial fold and sinus normal in position (*i. e.*, fold on brachial valve and sinus on pedicle)..... 22†.
22† Surface smooth.
CVII. *Ambocælia* (except *A. planoconvexa*).
22† Surface with concentric striæ..... 23*.

23* Sinus and fold undefined and shallow.
376. *Reticularia lævis.*
23* Sinus and fold defined and angular.
CV. *Martinia.*
22† Surface radially striate..... 326. *Spirifer radiatus.*
22† Surface minutely granular (seen under lens).
388. *Ambocœlia planoconvexa.*
xx. Mesial fold and sinus reversed in position.
CVIII. *Metaplasia.*
xx. Mesial fold and sinus lacking or faint..... 23†.
23† Beak of pedicle valve high and incurved; that of brachial not incurved. Shell nearly plano-convex.
XXVI. *Kutorgina.*
23† Both beaks incurved. Shell bi-convex.
380. *Reticularia perplexa.*
2222. Surface plicated ..... *yy.*
yy. Shell structure punctate..... 24†.
24† Small .... 24*.
24* Cardinal area present..... 20″.
20″ Cardinal area very high, giving the shell a semipyramidal form..... C. *Cyrtina.*
20″ Width much exceeding length, the shell thus lacking a semipyramidal aspect.
CII. *Spiriferina.*
24* Cardinal area absent. Umbo of pedicle valve truncated by a round foramen.
CXII. *Trematospira.*
24† Large, spiriferoid, with pedicle tube or syrinx in rostral cavity of pedicle valve..... CVI. *Syringothyris.*
yy. Shell structure not punctate..... 25†
25† Low fold on pedicle valve and sinus on brachial. 25*.
25* Shell pustulose, brachidium a spire.
CXIX. *Vitulina.*
25* Shell not pustulose, brachidium absent.
LX. *Scenidium.*
25† Well marked sinus on pedicle valve and fold on brachial.
26*.
26* Cardinal areas of the two valves subequal in height; plications angular, including fold and sinus; no brachidium..... LIII. *Platystrophia.*
26* Cardinal area of pedicle valve greatly exceeding that of the brachial; brachidium spiral... 21″.
21″ Cardinal area very high, form of shell subpyramidal, deltidium perforated.
CI. *Cyrtia.*
21″ Cardinal area variable, form not subpyramidal, deltidium absent or without perforations..... CIII. *Spirifer.*

THE DESIGN OF DIRECT CURRENT MOTORS.*

By CHARLES H. BEDELL.

In the discussion of the design of direct-current motors, it should be remembered that as far as the standard motor is concerned, the subject has been so thoroughly considered by many writers that it would be a waste of time to go over that ground. During the last two or three years the demand has been made for motors that would operate over a wide range of speed, a demand which the standard motor was not able to fill on account of commutator difficulties. Prior to the time when this demand was made, if a motor would operate at full load without sparking at 33 per cent. above its normal speed by means of weakening the field, it was considered a good motor, and if it would thus operate at 50 per cent. above its normal speed it was considered an unusually good machine. These well recognized specifications of a good constant speed motor suggest a definition of a variable speed motor, that is a variable speed motor is one which may be operated at speeds over fifty per cent. above its minimum speed. In applying this definition to machines of different types of field winding, the particular characteristics of each winding must be considered.

As the demand was made for variable speed motors which could be operated at from 100 per cent. to 500 per cent. above minimum speed, it is evident that radical changes in design must be made. What these changes should be, will of course depend upon the weak points of the standard motor and these will be considered first. In all direct current motors the current in each armature coil is reversed as its terminal commutator bars pass under each brush. Unless means are employed to reverse this current while the coil is short circuited by the brush, there will be a sudden change in the value of the current in the coil as it passes out from under the brush. This sudden change in current strength will make its presence known by sparking at the brush tip. The use of carbon brushes has caused an immense improvement over the condition existing when the old metal brush was used, due to the fact that its contact resistance with the commutator is far higher

* A paper read before the Electrical Engineering Society of Columbia University.

than that of the metal brush. This contact resistance with a given commutator bar will depend upon the area of the bar in contact with the brush. As the bar passes out from under the brush the area of contact reduces and therefore the contact resistance increases, thus tending to choke off the flow of current to that bar and force it to flow to the bar under the brush where the full area is exposed. In cases where the commutating conditions are not severe this property of the carbon brush is sufficient to cause the reversal of the current in the time the coil is passing under the brush. This should be the case in all reversible motors of the standard type, for in the reversible motor the brush must be placed at the neutral position.

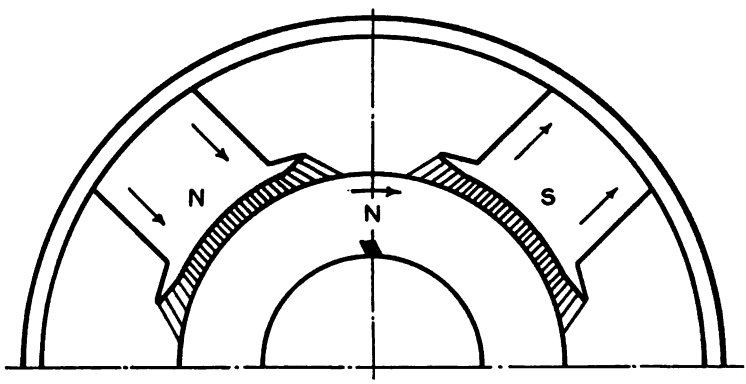

FIG. 1. Normal Field Excitation — Armature Current Small.

It might be well to point out that the enormous growth of the electrical industry has been due, or at least made possible by the advent of the carbon brush. Without its use it would seem that the street railway industry as we know it would be impossible. In cases where the contact resistance of the carbon brush is not sufficient to control the reversal of the current in the short circuited coil, other means must be employed to assist this reversal. The most common method is to give the brushes a backward lead. The coil that is short circuited is then cutting lines of force from the main field. The E.M.F. thus generated tends to reduce the current flowing in the coil, and set up a current in the opposite direction, that is, it tends to reverse the current. If this fringe of the main field is not strong enough to reverse the current in the time the coil is passing under the brush, sparking will result; or

if the fringe is too strong, the reversal will be carried too far, thus also producing sparking. It will thus be seen that by proper adjustment the reversal of the current in the short circuited coil may be made to take place in the time the short-circuit exists, and therefore no sudden change is made in the strength of the current as the coil passes out from under the brush.

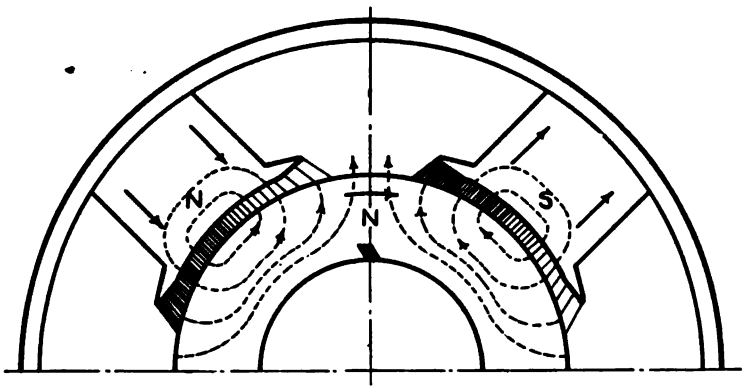

FIG. 2. Field Distortion due to Slight Armature Reaction.

One of the causes of sparking, when the brush is on the neutral line is due to the fact that the ampere turns on the armature set up a magnetic field between the pole tips of the main field. The coil undergoing commutation cuts the lines of force of this armature field and the E.M.F. thus generated tends to maintain the current in the short-circuited coil. By rocking the brushes back as mentioned above, the coil undergoing commutation is in the fringe of the main field. The condition existing at this point is that of two forces opposing each other. The ampere turns on the armature tend to send lines of force out, we will say, of the armature in the region of the short circuited coil. The more powerful main field overcomes this tendency, and the commutation takes place in a field which reverses the current in the time the coil is passing under the brush. From the above it will be seen that in the standard motor the main field is made use of to overpower the armature field and furnish the necessary field for commutation. If now the main field is weakened to produce higher speeds, a point is soon reached where that field is no longer powerful enough to overcome the armature field, and therefore no amount of shifting of the brushes will stop the sparking.

This is the weak point in the motor of standard design when applied to variable speed work. The field is weakened to produce the high speed, and in consequence the armature reaction destroys the commutating fringe. It will be noticed that at the instant when a powerful fringe is most required, at full load and high speed. that is the time when there is little or no fringe; and when the powerful fringe is not needed, that is the time when it is present, Changing the proportions of the machine will help matters somewhat, for example, making the armature very weak, and the field

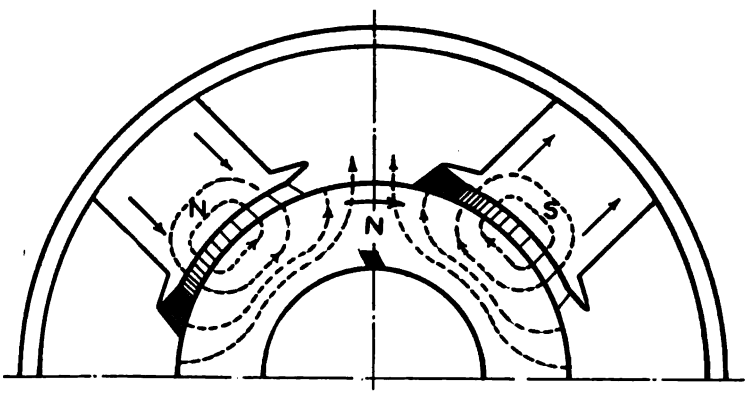

FIG. 3. Field Distortion due to Large Armature Reaction.

very strong with a large air gap. Such changes reduce the armature reaction, and help matters considerably, but they are only a help, and not a cure of the trouble, and in addition cause the machine to be very large for its output. The theoretically perfect variable speed motor should have the commutating fringe independent of the main field, and this fringe should change with the load. With these specifications in mind, the motor now known as the inter-pole motor was designed, having characteristics so nearly approaching the specifications that its forms of construction and behavior under test are worthy of careful examination.

As it is necessary that the commutating fringe be independent of the main pole, small auxiliary poles called inter-poles are used, placed midway between the main poles, with pole faces covering the region of commutation. In order that the proper commutating fringe may be obtained that would vary with the load, the inter-poles are wound with the necessary number of turns and connected

in series with the armature. Thus when the load on the armature is heavy, the ampere turns on the inter-pole are large, resulting in a powerful commutating fringe, and when the armature load is light, the excitation of the inter-poles is light, resulting in a weak

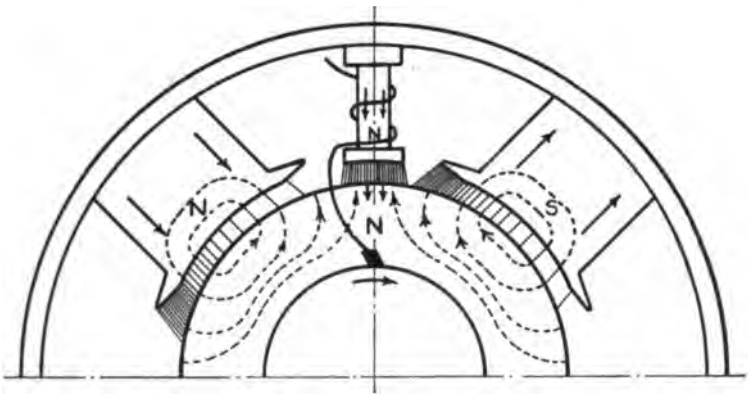

FIG. 4. Production of Commutating Field with Interpoles.

commutating fringe. It will thus be seen that by this construction the first of the two specifications for a theoretically perfect variable speed motor is satisfied, and the second one also, until the saturation point of the core of the inter-pole is reached. In the actual motor this saturation point is about 100 per cent. overload, so that it may be said that the second specification is practically satisfied. It may be thought that as we are not dealing with a straight line in the saturation curve of the inter-pole that the commutating fringe would not be sufficiently close to bring proportional to the load on the armature. Fortunately the qualities of the carbon brush allow quite a wide variation from exact proportionality, and the motors operate at maximum speed without sparking with any load up to the saturation point of the inter-poles. The question may be asked whether the same excitation is required on the inter-poles for a given armature load for both high and low speeds. Experiment has proved conclusively that if the excitation of the inter-pole is correct for high speed, it is also correct for all lower speeds. Although the same number of lines of force are sent into the armature from an inter-pole for a given load irrespective of the rate of rotation, yet the E.M.F. generated in the short circuited coil is proportional to the rate of rotation. Thus a high E.M.F. is provided for the very quick reversal of the current at high speed,

and a much lower E.M.F. provided for the slower reversal at the low speed. The commutating field produced by this form of construction is broad, and practically of uniform intensity over the interpole face, differing materially in this respect from the fringe of the main poles formerly used for commutating purposes. With the old method considerable of the main pole area was beveled off to produce the necessary breadth of fringe. The new method furnishes a commutating field better suited to the work, and the main pole is not robbed of its valuable area. As the main pole fringe is not used for commutating purposes, the main field may be of full strength up to the edge of the pole. It is necessary to skew the edge of the pole an amount equal to about one tooth and slot of the armature, to prevent humming of the armature teeth. By this construction one end of a tooth enters the powerful field before the other end, resulting in a dampening of any tendency to vibrate.

FIG. 5. General View of Field Frame.

Referring again to the standard reversible motor, it has been pointed out that the brushes must be on the neutral line, and that but little benefit is obtained from the main field to assist commutation. In this class of motors the qualities of the carbon brush are depended upon to prevent sparking. With the inter-pole construction, the brushes are also placed on the neutral line, and in

addition as powerful a commutating field as may be desired can be obtained to assist in producing correct commutation. It will therefore be seen that with the inter-pole construction, all motors are reversible with more perfect commutating conditions than can possibly be obtained with the old form of construction. This at the present time is of particular interest, as by this form of construction, motors for railway work can be operated with far higher voltages than is possible with the motor of standard design.

In reversing the direction of rotation of an inter-pole motor, the connection between the armature and inter-pole winding is not disturbed, that is the two portions are operated as a unit. Therefore it makes no difference as far as sparking is concerned whether the current flows in one direction or the other, or whether the machine be operated as a motor or dynamo. The machine will therefore stand the most severe tests of rapid reversing, or sudden changes in speed where the inertia of the moving parts causes the machine to operate as a dynamo, returning power back to the line. This feature of the machine has proved of great value in elevator work where part of the time the machine operates as a dynamo, preventing a heavily loaded car from falling too rapidly.

In the designing of machines along the old lines, some of the dimensions are limited by sparking conditions. For example it will not do to put more than a certain number of ampere turns per inch of periphery on the armature, as a larger number produces too great armature reaction. Similarly it will not answer to have too small an air gap for the same reason. With the inter-pole construction these conditions do not pertain, for no matter what the armature reaction may be over the face of the main pole, the inter-pole always gives the proper field for commutation. It follows therefore that radical changes in proportions may be made. The armature of the inter-pole motors as now constructed have considerably deeper slots than corresponding standard motors. The air gap also is less. On account of these two changes, the motors are considerably smaller than those of standard design, making it much easier to gear them to machine tools.

The change in the relative amount of iron and copper in the armature makes quite a change in the form of the efficiency curve. As the amount of iron is less, the hysteresis and eddy current losses are less. The increased amount of copper makes the C^2R armature loss greater. The full load efficiency is practically the

same as in the standard motor, but on light loads the efficiency is increased. The motors therefore show a much better all day efficiency, approaching more nearly to the condition of the transformer. In most installations this is of considerable importance for motors as a rule are run for a large portion of the time at considerably below full load. The modifications in design that have proved so satisfactory in the variable speed motor are also applicable to the constant speed motor, and a full line of these motors is manufactured up to 150 H. P.

As proper commutation can be obtained by means of inter-poles without depending too much upon the carbon brush, it would follow that variable speed motors can be built for high voltage circuits. This has been proved conclusively by many motors that have been built for 500 and 600 volt circuits, motors in sizes up to 10 H. P. having speed ratios of 1 to 4 and in sizes up to 125 H. P. having speed ratios of 1 to 2, all of them working absolutely without sparking.

ADJUSTMENT OF BENCH LEVELS.

By SAMUEL D. BLEICH.

In connection with the survey work conducted by the Rapid Transit Commission, several level parties have been sent out from the Sewer Division of the Commission under charge of Mr. Amos L. Schaeffer, Division Engineer, to establish bench marks along all the lines of the proposed subway routes. Several lines were run along the different avenues of Manhattan, and these were connected by cross-runs through many streets. As a result, all these lines comprised many closed circuits. It became necessary to adjust the field work so as to obtain for all the benches, elevations which would be geometrically consistent with one another.

The simplest method would be to consider each longitudinal line of levels separately. After obtaining average differences of elevations between successive benches or turning points of all the runs made along the line and beginning with an established elevation, it would be necessary to apply these averages with its proper sign in sequence to obtain the elevation of all the benches along this line.

But on assigning elevations to the benches according to this method along several longitudinal lines, it frequently occurred that the elevations thus established would yield material differences from the cross-runs made connecting the longitudinal lines. For instance, if bench elevations are established along the lines *abcd* and *ahgfe* independently of each other, it may happen that elevations will be assigned to *b* and *g*, *c* and *f*, or *d* and *e* which will differ considerably from the cross-runs made connecting these points.

It became apparent, that the adjustment should be made by using two longitudinal runs and two cross-runs, all four runs comprising one comprehensive closed circuit. The algebraic sum of the differences of elevation taken all around the circuit should equal zero. As generally happens, the algebraic sum as obtained from the field notes will differ from zero by a small amount, known as the error of closure for the circuit. This error should then be uniformly distributed along the entire circuit to make it a consistent whole.

But even this modification did not remove all sources for embarrassing discrepancies. The circuit considered comprised within itself smaller circuits, or a side of this circuit was in common with a contiguous circuit. The circuit *acfh* is made up of two smaller circuits; and also the side *cf* of this circuit belongs to the adjacent circuit *cdef*. With the adjustment made on circuit *acfh*, elevations will be obtained for *b* and *g* which may differ considerably from the cross-run between these points. And should the circuit *cdefc* be also adjusted, the elevations obtained for *c* and *f* from the first circuit adjustment may differ materially from what would be obtained for these points in this second circuit adjustment.

It would be possible by modifying some elevations as indicated by the discrepancies practically to eliminate most of the inconsistences brought to light by this method of adjustment. But these modifications, as reasonable as they may be, do not obey any definite

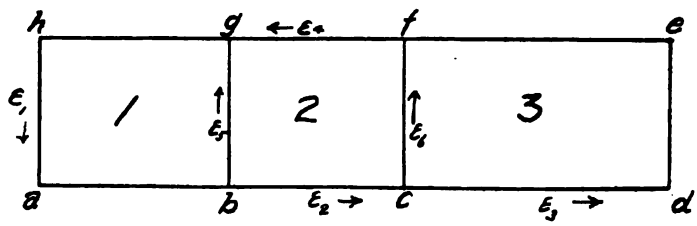

FIG. 1.

law. The problem arose, to devise some logical method for the distribution of the errors of closure for a network of closed circuits, whereby the elevation of the benches, as determined by a rigorous procedure, would be consistent with one another. This problem can readily be solved by the application of the principle of least squares; and in what follows the derivation of the formulas giving the most probable distribution of the errors in elevation will be outlined.

Let circuits 1, 2 and 3 be made counter-clock wise.

Let E_1 = algebraic sum of differences of elevation of circuit 1.

E_2 = algebraic sum of differences of elevation of circuit 2.

E_3 = algebraic sum of differences of elevation of circuit 3.

ϵ_1 = error in *ghab* in direction of arrow.

ϵ_2 = error in *bc* in direction of arrow.

ϵ_3 = error in *cdef* in direction of arrow.

ϵ_4 = error *fg* in direction of arrow.

e_5 = error in *bg* in direction of arrow.
e_6 = error in *cf* in direction of arrow.
L_1 = length of *ghab*, etc., etc.

The geometrical conditions which must be satisfied for the three circuits are:

$$E_1 + e_1 + e_5 = 0 \quad (1)$$

$$E_2 + e_2 + e_6 + e_4 - e_5 = 0 \quad (2)$$

$$E_3 + e_3 - e_6 = 0. \quad (3)$$

Since the probable error in level work varies with the square root of the length of course, the errors e_1, e_2, etc., have not the same weight, in general. Each one of the e's must be divided by the square root of the length of course to which it has reference, to obtain errors of the same weight. Thus $e_1/\sqrt{L_1}$, $e_2/\sqrt{L_2}$, etc., have the same weight.

According to the theory of least squares, these errors will most probably be distributed so as to make the sum of the squares of the errors reduced to equivalent weights, a minimum. Therefore,

$$\frac{e_1^2}{L_1} + \frac{e_2^2}{L_2} + \frac{e_3^2}{L_3} + \frac{e_4^2}{L_4} + \frac{e_5^2}{L_5} + \frac{e_6^2}{L_6} = \text{minimum.}$$

Differentiate

$$\frac{e_1}{L_1} de_1 + \frac{e_2}{L_2} de_2 + \frac{e_3}{L_3} de_3 + \frac{e_4}{L_4} de_4 + \frac{e_5}{L_5} de_5 + \frac{e_6}{L_6} de_6 = 0. \quad (4)$$

Differentiate equations (1), (2), and (3)

$$de_1 + de_5 = 0 \quad (5)$$

$$de_2 + de_6 + de_4 - de_5 = 0 \quad (6)$$

$$de_3 - de_6 = 0 \quad (7)$$

Multiply equation (5), (6), and (7) by x, y, and z respectively, add them, and then subtract equation (4); there results

$$\left(x - \frac{e_1}{L_1}\right) de_1 + \left(y - \frac{e_2}{L_2}\right) de_2 + \left(z - \frac{e_3}{L_3}\right) de_3 + \left(y - \frac{e_4}{L_4}\right) de_4 + \left(x - y - \frac{e_5}{L_5}\right) de_5 + \left(y - z - \frac{e_6}{L_6}\right) de_6 = 0.$$

Let x, y, and z be determined by placing the first three coefficients equal to zero. Then since the last three e's are independent of each other, the coefficients of these must be equal to zero. We have therefore

$$x - \frac{e_1}{L_1} = 0 \qquad (a)$$

$$y - \frac{e_2}{L_2} = 0 \qquad (b)$$

$$z - \frac{e_3}{L_3} = 0 \qquad (c)$$

$$y - \frac{e_4}{L_4} = 0 \qquad (d)$$

$$x - y - \frac{e_5}{L_5} = 0 \qquad (e)$$

$$y - z - \frac{e_6}{L_6} = 0 \qquad (f)$$

Multiply equations (a), (b), (c), etc., by L_1, L_2, L_3, etc., respectively. Thus reduced add equations (a) and (e) and reduce by equation (1)

$$(L_1 + L_5)x - L_5 y + E_1 = 0 \qquad (A)$$

add equations (b), (d), and (f) and subtract equation (e) and reduce by equation (2)

$$- L_5 x + (L_2 + L_6 + L_4 + L_5)y - L_6 z + E_2 = 0 \qquad (B)$$

subtract equation (f) from (c) and reduce by equation (3)

$$- L_6 y + (L_3 + L_6)z + E_3 = 0 \qquad (C)$$

Equations (A), (B), and (C) give values for x, y, and z; and with these values e_1, e_2, e_3, etc., may be computed from equation (a), (b), (c), etc.

As a numerical illustration of the use of these equations in the adjustment of levels, assume

$$L_1 = 3 \text{ miles}$$
$$L_2 = 1 \text{ mile}$$
$$L_3 = 4 \text{ miles}$$
$$L_4 = 1 \text{ mile}$$
$$L_5 = 1 \text{ mile}$$
$$L_6 = 1 \text{ mile}$$
$$E_1 = +.031 \text{ feet}$$
$$E_2 = -.027 \text{ feet}$$
$$E_3 = -.040 \text{ feet}$$

Substituting in equations (A), (B), and (C), there result

$$4x - y + .031 = 0$$
$$-x + 4y - z + .027 = 0$$
$$-y + 5z - .040 = 0$$

From which

$$x = -.0058$$
$$y = +.0078$$
$$z = +.0094$$

These substituted in equations (a) to (f) give

$$e_1 = -.017$$
$$e_2 = +.008$$
$$e_3 = +.038$$
$$e_4 = (+.008) = +.007$$
$$e_5 = -.014$$
$$e_6 = -.002$$

Because the numerical work is carried out to but three decimal places, a very slight discrepancy will be obtained on trying to satisfy equation (2). But this discrepancy is removed by making

$$e_4 = +.007.$$

Similar formulas may readily be obtained in the same manner for a more complicated system of circuits. In all cases, all the equations obtained will be simple and linear in form.

Adjustment by the method of least squares may appear laborious. But as opposed to the other methods of adjustment, it possesses the great advantage of being direct. Moreover it does not

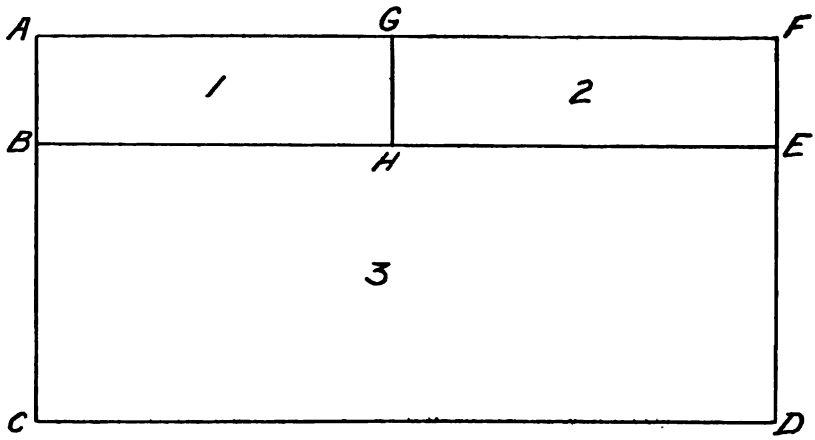

FIG. 2.

result in embarrassing discrepancies, which the other imperfect methods invariably do; and in this respect it will prove time-saving.

To illustrate the ease with which a solution may be made for a different system of circuits than that used in the analysis take the network of circuits in Fig. 2.

The actual errors of closure obtained for the circuits in Fig. 2 were:

$$E_1 = + 0.'016.$$
$$E_2 = - 0.037.$$
$$E_3 = - 0.009.$$

All these circuits were made counter-clock wise.

The lengths of the stretches are:

$$AG = GF = BH = HE = 2.4.$$
$$AB = GH = FE = 0.8.$$
$$BC = ED = 3.4.$$
$$CD = 4.8.$$

The unit of distance being 1000 feet.

By studying equations A, B and C with reference to Fig. 1 and

working by analogy, the following equations will be obtained for Fig. 2.

$$6.4x - 0.8y - 2.4z + .016 = 0$$
$$-0.8x + 6.4y - 2.4z - .037 = 0$$
$$-2.4x - 2.4y + 16.4z - .009 = 0.$$

From which

$$x = -.00127$$
$$y = +.00609$$
$$z = +.00126$$

Probable error in $GAB = 3.2x = -.004$
Probable error in $BCDE = 11.6z = +.015$
Probable error in $EFG = 3.2y = +.019$
Probable error in $BH = 2.4(x-z) = -.006.$
Probable error in $HE = 2.4\,(y-z) = +.012$
Probable error in $HG = 0.8(x-y) = -.006.$

By modifying the level work along the different stretches by the probable errors obtained, the closures of all the circuits will be made perfect.

DINNER OF THE CIVIL ENGINEERS OF COLUMBIA UNIVERSITY.

On the evening of April 14 the graduates of the School of Civil Engineering of Columbia University met at a dinner in the Hotel Astor. There were present over one hundred, representing classes from 1876 to 1906 inclusive. The committee in charge of the arrangements, to whom much credit is due for the success of the dinner, was composed of the following gentlemen: Prof. Wm. H. Burr, Prof. Ralph E. Mayer, '76; Mr. Fred. R. Lord, '91; Mr. Henry B. Machen, '98; Mr. Myron S. Falk, '99. The toastmaster of the evening was Mr. Wm. Barclay Parsons, and the speakers included President Butler, Professor Burr, Mr. Henry F. Hornbostel and President Alexander C. Humphreys, of Stevens Institute, whose speech we are enabled to give in part below.

C. E. M.

REFORM.

We are constantly hearing of the need of reform. We are constantly asked to subscribe money and effort to some definite project in the line of reform. We are constantly forced to recognize that in things social, political and commercial there is room for reform in plenty. We have with us honest and competent (real) reformers, amateur reformers, graft reformers and yellow journal reformers.

It seems to me that we might be able to apply more efficiently our efforts in the many good causes presented to us if we recognized, and constantly kept in mind, the fact that there always has been need of reform and there always will be. Reformation should be a continuing rather than a spasmodic process. The laws on the statute book should be enforced and laws which cannot be enforced evenly and completely should not be enacted. Such laws on the statute book only increase the need of reform. But it is so much easier to pass a new law and then dismiss the matter comfortably from our minds than to be constantly vigilant in the enforcement of laws already available.

We see the same inclination in the weaker brethren, young and old, that we may be trying to encourage to better things. The means at their present disposal they do not use, for that means steady effort on their part, but they are constantly saying if they

only had so and so they could make a success of life. It is the thing that someone else can do for them, not the thing they can do for themselves, the lack of which they plead as an excuse for constant failures.

Real reform is serious work and is not safely placed in the hands of the inexperienced, the visionary, the fanatic, and certainly not in the hands of the dishonest. This breezy way of ridding ourselves of evil, once for all, by the passing of a law, reminds me of the difference between the English and American officials in the matter of paving. Our officials arrange for a paving scheme, finish the work and assess the cost and then you can hear them say with a sigh of relief — "Well, that's done." The English officials contemplate the new pavement and say — "There's one *more* thing to be taken care of."

There are certain directions in which we are to-day especially in need of reform, and reform is hindered if not prevented by the lack of information and the misinformation of the public. This is a particularly serious condition to meet in the case of a country where the government is — "of the people, by the people, for the people."

The questions I have reference to are largely industrial and therefore the engineers of the country must bear a definite responsibility in connection with the ignorance that prevails, not only by reason of the fact that they fail to do their part as educators, but because too frequently their own ignorance leads them personally into error. Take for instance the so-called struggle between capital and labor. Should we not at once discriminate and so recognize that the struggle generally is between the manipulators of capital and the manipulators of labor? Both of these forces have made and are continuing to make mistakes — to put it mildly. These "mistakes" not infrequently degenerate into crimes, some of them hideous in their results. The innocent capitalist and the innocent wage-earner suffer from the wrong acts of their leaders.

These leaders are keen to group their followers in two opposing camps, while the followers should see that there is no sharp line of division. Generally the capitalist is a laborer, and the wage-earner is a capitalist as soon as he begins to save. The savings banks and the life insurance companies are regarded as being definitely in the camp of the capitalists and still in these institutions the wage-earner has an interest which surely should be readily

recognized. In this and many other connections, injustice done to capital must react unfavorably upon the wage-earners.

But the manipulators of these forces supposed to be rivals are constantly struggling for the ascendancy and the innocent followers suffer in any case.

And here is discovered the baneful influence of what I believe is the most dangerous element in our life of today — that of the yellow press. The mistakes made on either side *may* originate in mistakes of judgment. The desire to improve conditions may be present though expressed through injudicious and unwise methods. But the yellow journal has no such honest intentions — here the desire is only to cultivate misunderstanding for selfish ends.

The daily press must be necessarily largely superficial in its treatment of large subjects. While it serves a great end for good, there is no little danger involved even when the desire is to discuss questions judicially.

Not a man in this room but has had his faith in the accuracy of newspaper reports shaken by finding more or less inaccuracy in the accounts of transactions in which he has been concerned. Thus we are tempted to be severe in our criticisms and then in fairness we come to wondering how it is that so much that is accurate can be prepared for us when it has to be done by men always working under high pressure.

If the chances of error are so great in the case of papers honestly trying to reflect the truth, how great is the danger of being influenced in our opinions by the yellow journals, which at the best are only trying to create a sensation, and too frequently are intentionally cultivating distrust among the classes which go to make up our communities. Am I exaggerating when I say that today the yellow press is *the* curse of this country, that it is an ever active agent in cultivating the worst passions, passions which will always be ready to break through their confines as long as human nature is human nature? Then it follows that the yellow press is the greatest obstacle in the way of efficient reform.

Mistakes are made innocently by well meaning reformers — enthusiasts and inexperienced, influenced by what they believe to be righteous indignation. These men we can respect for their motives, and this in spite of the disastrous effects which too often follow their ill-advised efforts at reform. But contempt, and contempt alone, we have for those who calculatingly encourage these amateur

reformers, hoping thus to rise upon the failure and disgrace of others. And here the yellow journal is the chief offender. But, thank God, good sometimes comes from actions inspired by wrong motives. Some do good in spite of themselves.

Recklessly conducted reform movements may do some good, though the innocent are called to suffer with the guilty and other evils are developed as the occasion for future reforms. But as engineers, trained to strive always for efficiency, how wasteful appears this process at the best. If it remains for the ignorant enthusiast to rouse us out of our lethargy, cannot we at least come in later to help in developing permanent remedial measures based upon a more complete knowledge of industrial and commercial conditions?

Let us consider a case of so-called reform near home. In the case of a certain industry public clamor had been cultivated by the yellow journals and especially by *the* yellow journal. No doubt cause had been given for complaint, but the causes were specific and not general. But this was enough for the yellow journal to claim that every feature of the management was wrong and nothing was or could be fair and honest about the management. The dear people, whose welfare was so much to the yellow journal, must be protected from the robbers.

First an investigation was had by a committee from Albany. This is generally spoken of as a "most thorough investigation." The thoroughness is seen when we find that upon the recommendation of this committee a law was passed requiring the company to distribute its product under conditions that would *in the effort* to conform thereto necessarily deprive the consumers of a satisfactory supply and even then the company would be subject to fines as often almost as the authorities cared to make the inspections.

A member of the committee had had a little experience in this industry as a director, and as you gentlemen know, our directors all understand every detail of our several businesses. This gentleman, I understand, was authority for the law as passed, for he said that in the company he was interested in they were complying with these conditions. Even if feasible in the committeeman's company, it did not follow that it was feasible in New York, for differences of level have a distinct bearing upon the problem in connection with the law of gravitation. But, as far as I know, this simple element of the problem was not once considered by the committee.

And are not we engineers continually made to face propositions which are based upon statements which we know are untrue and must of necessity be untrue? I instance one which I have struggled with for the past thirty-odd years in many different forms: That from a pound of coal having a total calorific value of 14,000 B.T.U.s, by the process under consideration 28,000, 42,000, 56,000 or more B.T.U.s could be obtained. And when we say such a result is impossible, the yellow journal reporter says: "These engineers have always been wrong and have always opposed progress when a new idea has been brought forward; for instance, see the history of the electric light, the telegraph and the telephone."

But to come back to our case. As the result of this investigation which was so remarkable for its completeness, a law was passed to place this industry under the control of a commission. The business being one of much complexity, it was reasonable to expect that the Governor would not only try to appoint able and reputable men, but men already qualified to deal with the problems to be presented, and men not subject to political pressure.

The undertaking was a difficult one even for a competent board — competent I mean by reason of past training along specific lines. As nearly every branch of engineering is involved, should we not expect that on such a Board there would be at least one engineer? As many questions of business policy and management are involved, should we not expect that there would be at least one member with a broad business experience? No — all three appointees were lawyers and all three apparently subject to political pressure. I wish it distinctly understood that I make no reflection on these gentlemen personally; I am finding fault only with the system. Furthermore, none of them apparently had had such a qualifying experience in commercial matters that they could readily take in the full and true meaning of a statement of accounts. Fortunately, one was a judge, and so had had experience in balancing conflicting evidence. Speaking from a fairly full and broad experience in such matters, I deliberately express the opinion that if such a Board is to be recruited from one class or profession only (though there is no necessity for such a course), a better result could be obtained from a board composed of three engineers than from one composed of three lawyers, and especially if these engineers were accountant-engineers.

I firmly believe that selected engineers are as competent to de-

cide questions of law as selected lawyers are competent to decide questions of engineering. But in England, or even in the State of Massachusetts, where they have had experience with commissions, appointments are not made from one class of citizens. I am making no attack on lawyers nor on politicians, but I claim that men who are called upon to act in matters so important and so charged with technicalities should have had previous experience to qualify them to act intelligently; and above all they should be under no political obligations.

Consider the one important element of depreciation. Is any man qualified to appraise this element of cost, if he has had no direct experience in depreciation of plant and no experience in accounts to qualify him to accurately gauge the statements presented? And still this one element if left out of the statement of cost, or excluded as it was in part in the case referred to, may spell ruin to the owners.

Again, under such a system as the one referred to, if it can be so dignified, those upon whom the responsibility is placed are not left to exercise their best judgment, but while trying, perhaps conscientiously, to arrive at the truth are subjected to pressure from the so-called public opinion — but more correctly public clamor sedulously cultivated by a dangerous yellow journalism.

In this case the course pursued is more definitely open to criticism, for the Legislature which passed the law and the Governor who appointed the members of the Board put pressure upon the Board to render a decision while the investigation was not yet completed. Finally the Legislature took the matter out of the Board's hands by passing a bill to cover some of the cases still under advisement.

What a parody upon justice and what a reflection upon themselves, in having first committed the matter to a board of their own making, presumably that the facts might be developed by a dispassionate and intelligent investigation, as a guide to any action to be taken, and then taking the matter out of the hands of the Board because the investigation necessarily took more time than the politicians believed to be necessary.

The reason frequently quoted as justifying this action was that the legislature's previous investigation by its committee had been so thorough as to make the commission's investigation unneces-

sary. I have already shown how thorough this first investigation was.

It goes without saying that the public clamor which thus influences our legislators is not cultivated even by the conscienceless yellow journal without there being a basis for complaint.

Some of our public service corporations do furnish occasions for complaint, though I believe that most often the causes arise in spite of intelligent and determined efforts on the part of the managers to eliminate the evils complained of. As long as human nature is human, an army of employes (free American citizens all) must give occasion for complaint and an army of patrons will surely register unjustifiable complaints. We all know that no matter what efforts may be made by those managing our public service corporations, complaints, some just and some unjust, will be made. I am not trying to justify inefficiency or dishonesty, but I believe in fair play and a discriminating criticism. Here is a serious situation and it is a situation in which much harm and much injustice to the innocent may be done. And here is where the engineer, trained to analyze and balance conflicting testimony, must accept the responsibility that accompanies specific knowledge and experience. What is excusable in the citizen not so trained is not excusable in the one who has had unusual opportunities to obtain exact information or even has the ability to gain exact information. The man so trained cannot plead ignorance if he allows his opinions to be made for him by the writers in the yellow journals who are under contract to write along certain predetermined lines, who use what can be twisted to their purpose and ignore all else.

Much of the trouble between capital and labor — or the manipulators of each — which the yellow journals aim sedulously to cultivate, the engineer should be prepared to minimize. He, as the director and manager of industrial undertakings, should be prepared to stand between capital and labor and protect capital and labor from the misunderstandings initiated by the manipulators on each side and cultivated by the yellow journals.

Here is an opportunity for the engineers of the United States — for us, gentlemen — to assist in practical reform.

And the country never stood more in need of reform of this kind than it does to-day.

ALUMNI AND UNIVERSITY NEWS.

DEPARTMENT OF MINING.

In the November, 1905, issue of the QUARTERLY, pages 75 to 77, reference was made to a change inaugurated during the preceding summer in the mode of conducting the Summer School of Mining. The larger part of the class was divided into squads of from two to four men and sent to a number of different mines, arrangements having been previously made with the managements of these mines whereby the students would be accorded the necessary permission and facilities for carrying on their course of study. Each member of the class was provided with a printed outline of the work, containing such detailed instructions and suggestions as would enable him to take notes and make sketches of methods and plant in an intelligent manner. On their return to the School of Mines in the fall the students were required to submit their note-books for criticism and marking.

The results of this departure from the former method of conducting the summer school work were such as to lead the Department of Mining to repeat the experiment during the past summer. It has been found again that the work has been done satisfactorily and is up to the standard which has been maintained for so many years in previous summer schools. The considerations which led to this departure were stated in the article referred to above and need not be repeated here.

In 1905 the total number of students sent into the field was 41, of which 34 were without instructors from the department. This year the class numbered 40, of which 32 were either in independent squads or else secured positions for working in mines throughout the entire summer. The remaining 8 students formed a small class conducted in the regular manner, which went to the Michigan copper and iron districts in charge of Mr. Kurtz and Dr. Crane. A note as to the work done by this class is printed below. R. P.

The summer class in mining was held at the Wolverine and Mohawk mines of Keweenaw Point, Mich., during the months of June and July. Mr. Kurtz proceeded to the district about a week in advance of the students in order to complete the necessary arrangements for the work. Dr. Crane, who assisted with the work, reached Calumet on June 17, on which date the students also arrived. Work was begun on the 18th, with headquarters at Calumet, which is about two miles distant from the Wolverine mine and four from the Mohawk.

Through the courtesy of Mr. Fred Smith, the resident agent, and of the other officers of the staff, a detailed study of the mining operations and mine plant was carried on, together with a week's practice in underground surveying. Owing to the distance of the Mohawk mine from Calumet and poor facilities for getting to and from the mine, most of the surface work, and all of the surveying, was done at the Wolverine, where extensive workings and equipment were accessible. Four weeks were spent at this mine, during which time all of the detail work was done,

including visits of several days at the Mohawk, short visits to the Wolverine and Mohawk mills, Traverse Bay, and more or less detailed study in and about the surface works of the Calumet and Hecla, Tamarack, Centennial, Kearsage, Allouez and Ahmeek mines.

Mr. Kurtz left Calumet on July 9, the surveying work having been completed, while Dr. Crane continued with the class at Calumet until July 17, when headquarters were changed to Houghton. From Houghton excursions were made to the Dollar Bay copper wire drawing mill, the Calumet and Hecla concentrating works and smelters, the Quincy mill and smelter, and the Baltic mill at Red Ridge. At the Baltic mill the famous steel dam, which impounds water for both the Atlantic and Baltic mills, was seen. Also, at the kind invitation of Mr. F. W. Denton, a day was spent visiting the Trimountain mine, where a filling method is employed. This was by far the most interesting method of mining seen in the copper country and, not being employed in any other mine in the United States except the Baltic, is especially noteworthy.

From Houghton the class went to Ishpeming, in the Marquette iron district, arriving there on the 22d of July.

By the kind permission of Mr. Duncan, agent for the Cleveland Cliffs Co., the Lake mine and the mine located near the site of the old Barnum mine were visited. Mr. Johnson, agent for the Oliver Iron Mining Co., gave permission to visit Section Sixteen mine at Ishpeming and the Blue mine at Negaunee. In these the methods of mining both hard and soft ore were seen. The top-slice and the sub-drift methods of mining are employed in the soft ore mines, and owing to the more or less irregular occurrence of the ore and variations in grade many modifications are found to be necessary. Further, the milling system, as adapted to underground work, is being introduced.

One day was given to a detailed study of the surface works at Ishpeming, where there are some fairly recent steel mine constructions and up-to-date installations of air compressors and hoisting engines.

The ore docks at Marquette were visited, where was found an excellent opportunity to observe the method of construction and erection of the docks and ore-pockets, extensions being then in progress.

On July 26 work was completed and the class dismissed.

W. R. C.

DEPARTMENT OF CIVIL ENGINEERING.

The only change in the personnel of the teaching staff of the Department of Civil Engineering results from the resignation of Mr. Walter T. Derleth, Class of 1904, to enter practical work. Mr. Frank H. Sewall, C.E., Class of 1906, has been appointed to the assistantship.

At the close of the last academic year Mr. Black, who has been connected with the department since his graduation in 1894, was advanced to the grade of Adjunct Professor.

The department gives instruction to students in Electrical Engineering in the subject of Hydraulics for the first time this year. Hereafter the graduate electrical engineer will be better equipped on account of the additional instruction to deal with problems of water power development which are so closely allied with electrical engineering.

The problem work in resistance of materials is being done by students on assigned afternoons under the supervision of one of the assistants in

the department after the same general plan as has been followed during the past two years with the classes in railway surveying.

The Summer School of Surveying was held as usual at Camp Columbia, Morris, Conn. The school opened on June 2, and closed on September 12. The attendance during the season numbered 165. The greatest number of students present at one time was 104. Several men completed two courses and a few completed three. Seventy-one students registered in the first year course Civil Engineering 15 and of these 56 completed all the required work. The remaining 15 students completed three out of the four required surveys. Eighty-four students registered in Course 16 Civil Engineering and of these 74 completed the course and 10 completed four out of the five required surveys. The hydrographic squad, Course 16a Civil Engineering numbered 24 men all of whom completed the work. Sixty-seven men took the course in railroad surveying, Civil Engineering 17, and of these all but one completed the course.

The weather conditions during June were favorable for field work. Frequent rain during July delayed progress. August was again generally favorable, especially the latter half of the month. September was also favorable. The maximum recorded temperature during the session occurred at 3 P. M. on August 5, and August 7, being 94° F. The minimum temperature occurred at 3 A. M. June 12, being 41° F. The following table shows the average daily maximum and minimum temperature for each of the months, June, July, August and September. These maximum and minimum temperatures occurred generally at about 3 o'clock P. M. and 3 o'clock A. M. respectively.

Months.	Average Daily Maximum.	Average Daily Minimum.
June.	77.4°	58.4°
July.	83.3	62.9
August.	82.4	63.5
September, 8 days.	74.9	57.6

The health of the men in Camp was excellent. There was during the entire summer only one case of sickness among the students, and that was a threatened attack of appendicitis which yielded to treatment so that the patient was out again within seven days.

The improvements recently made at Camp added much to the convenience and comfort of the students. The water supply and sewage disposal systems were finished early in the school session and proved to be most satisfactory and efficient. Sewers were laid connecting the kitchen and the bath house and closets with the newly installed septic tank so that the wastes were all taken care of in the most sanitary manner. The supply of water from the spring located in a protected region about 2000 feet from the Camp is one of the greatest blessings of the school. The water is soft and cold and remarkably pure. The flow of the spring rarely falls below 20 gallons per minute.

The officers' headquarters and the instrument building, the walls of which are being made of stone, are as yet unfinished. The first when completed will add to the convenience and comfort of the instructing staff, and the instrument building, because of its construction and isolated location, will reduce the fire hazard upon the very valuable equipment of

field instruments. The Y. M. C. A. building furnishes a comfortable lounging room for students on rainy days and cold evenings. It is very much appreciated. The instructing staff of the Summer School consisted of Professor Lovell in charge, and the following assistants, all graduates of Columbia: Mr. C. E. Morrison, C.E., '01, principal assistant and assistant in charge of stadia work, solar work and mining surveys; Mr. R. deC. Green, C.E., '06, assistant in charge of topographic surveys; Mr. J. K. Finch, C.E., '06, assistant in charge of hydrographic surveys and a part of the first year work; Mr. R. S. Baylis, C.E., '06, assistant in charge of farm surveys and city surveys; Mr. F. H. Sewall, C.E., '06, assistant in charge of the instrumental equipment and levelling and exact angle and tape measurements. Each assistant during the last four weeks had charge of one or two parties of students engaged on railroad surveys. Mr. W. M. Carpenter and Mr. H. A. Thomas were engaged during the summer in making a complete boundary and topographic survey of the University property at Camp Columbia.

DEPARTMENT OF ELECTRICAL ENGINEERING.

During the summer, Professor Crocker attended the conference of the International Electro Technical Commission at London, as one of the two representatives of the American Institute of Electrical Engineers. He has been reappointed Chairman of the Standardization Committee of the Institute, and has also been for the last six months a member of the Government Advisory Committee on fuel and building materials which was appointed by the President.

The following promotions and appointments in the department have been made.

M. Arendt from lecturer to instructor.

Ernst S. Holcombe, M.E., Cornell 1901, has been appointed lecturer and in direct charge of the instrument and standardization laboratory.

S. S. Watkins, E.E., Columbia 1906, appointed assistant in charge of the direct current laboratory; and C. Otto von Dannenberg, Bachelor of Engineering, Union College 1906, has been appointed assistant in charge of the alternating current laboratory.

During the past year, Professor Crocker and Mr. Arendt have revised the "Practical Management of Dynamos and Motors" which now appears in the sixth edition, entitled "The Management of Electrical Machinery."

Professor Sever and Mr. Townsend have recently completed the revision of their laboratory note book, "Laboratory and Factory Tests in Electrical Engineering."

Professor Sever has been appointed by the President of the Institute, Secretary of the Institute Committee on National Electric Code.

In the Budget of this year, an appropriation of $3,500 was made for the use of the Electrical Engineering Department for the purchase of new qeuipment for its laboratories. There have been ordered a General Electrical Oscillograph, a motor dynamo set, a number of important instruments, and a constant current arc lighting outfit.

A valuable course in Hydraulics has been established for the Electrical Engineers, the theoretical and development portion being given by the Civil Engineering Department, and the kinematics of the subject, as well

as the laboratory work, being given by the Mechanical Engineering Department.

G. F. S.

DEPARTMENT OF MECHANICAL ENGINEERING.

During the past summer the mechanical engineering laboratories have been extended to occupy some of the rooms vacated by the Department of Mining. One of these rooms is now used for the making of fine measurements and the calibration of instruments and apparatus; the other two for a shop and for gas and oil engine work respectively.

There is being conducted at the present time a series of experiments on the value of alcohol versus gasoline as a fuel in small exploding engines, for the Department of Agriculture. The results of these experiments will be published by the Department of Agriculture in the form of a bulletin, to be issued on January 1, 1907, at which time the tax on denatured alcohol will be removed.

C. E. L.

DEPARTMENT OF PHYSICS AND MECHANICS.

Professor Joseph C. Pfister, who has been absent on leave during 1905–6, has resumed his duties, having much improved in health.

Course 9 (formerly 21) in mechanics, heretofore given to the second year class in applied science, has been transferred to the first year. In consequence of this change during the present academic year, Professor Pfister will instruct the second year class in two sections, three hours each per week; while the first year class will be in charge of Professor Tufts and Drs. Pegram and Davis in three sections.

J. C. P.

It is with great regret that we have to inform our readers of the death of Professor Edmund Howd Miller which occurred on November 8, 1906.

The following resolutions from the Columbia University Chemical Society have reached us in time for insertion in this issue which had already gone to press. A more extended notice regarding Professor Miller will appear in the next number of THE QUARTERLY.

Whereas, it has seemed fit to Divine Providence to remove from our midst our beloved friend and fellow worker, Professor Edmund Howd Miller,

Therefore, we hereby instruct the secretary of the Society to express to the family our heartfelt sympathy with their grief, and our full appreciation of the great loss suffered not only by us, and by Columbia University, but also by the chemical profession throughout the world.

Resolved, further, that the secretary be instructed to publish this Resolution as far as possible in both the University and in the professional publications.

For the Society,

R. M. FRENCH,
P. A. BOECK,
E. R. ALEXANDER,
D. WHIPPLE.

BOOK REVIEWS.

Mica and the Mica Industry. By GEORGE WETMORE COLLES, M.E., M.Sc., Member American Society Mechanical Engineers. Philadelphia, The Franklin Institute, 1906. 130 pp., 25 illustrations, 11 diagrams. Price $2.00.

This monograph first made its appearance several years ago in the Journal of the Franklin Institute. Since then it has heen revised and amplified by the author, after the accumulation of further data. An extremely interesting book has resulted, on a subject concerning which there is but a small amount of published information. The methods of mining mica and preparing it for the market have little in common with those followed in the production of most of the other useful minerals.

An outline of the mineralogy of mica is first given, including the chemical constitution and physical characteristics of the several varieties. Then follows the geology, geographical distribution and history; the methods of mining and the preparation for the market of the various commercial forms of mica, together with its chief uses, viz., electric insulation, glazing, manufacture of lubricant and as an ingredient of wall-paper pigments. An important chapter is that on the statistics of the mineral, comprising 30 pages of matter with many statistical diagrams. The author's style is concise and clear, and a good index adds to the value of the book.

R. P.

Notes on Metallurgical Mill Construction. Edited by W. R. INGALLS. New York, The Engineering and Mining Journal, 1906. Pp. 256. Illustrated. Price, $2.00.

Like its predecessors, edited by T. A. Rickard, on Pyrite Smelting, Economic Mining and Sampling and Valuation of Mines, this book is substantially a reprint of articles previously published in the Engineering and Mining Journal. It comprises seven parts, entitled: Brickwork and Concrete, Building Construction, Ore-crushing Machinery, Driers and Drying, Conveyors and Elevators, Disposal of Tailings, and finally several short articles on Miscellaneous subjects, such as: Pipe Line Construction, Accidents to Motors and Dynamos, Rubber Belting, Alloys for Bearings, etc.

Many of the articles, especially those dealing with Building Construction, first appeared in the Journal as editorials; several others are abstracts of papers originally presented to various technical societies — for example, the one on the Dry Crushing of Ores, by Philip Argall, who was awarded for it a medal and premium by the Institution of Mining and Metallurgy. Still others are brief discussions of a variety of matters relating to modern practice in the construction and operation of mills and metallurgical works. There are 40 cuts and diagrams, and a general index. While the book is by no means exhaustive, it is nevertheless both useful and suggestive. In respect of details of construction it contains much that is not to be found in treatises or hand-books on the milling and

concentration of ores, and presents concisely the the views of a number of practicing engineers on various debatable points in method and plant.

R. P.

Handbook of Mathematics for Engineers and Engineering Students. By J. CLAUDEL. Translated and edited by OTIS ALLEN KENYON. New York, McGraw Publishing Company, 1906. Pp. ix + 708. Price, $3.50 net.

The scope of this volume may be indicated by noting that it opens with a presentation of the Arabic and Roman systems of arithmetic notation and numeration, and closes with computations of moments of inertia by means of the integral calculus. The vast intervening territory is divided into six parts and treated in succession under the captions: Arithmetic (166 pp.), Algebra (79 pp.), Geometry (121 pp.), Trigonometry (94 pp.), Analytic Geometry (90 pp.), Elements of Calculus (78 pp.).

Mr. Kenyon has inserted various useful tables and certain sections dealing with such matters as annuities, insurance, bank discount, and United States weights and measures; but in the main both the content and general style of the work are drawn by an excellent translation from the seventh edition of Claudel's "Introduction à la Science de l'Ingenier."

While the work is called a hand-book, it is rather thick and heavy for that use, and it might well be described as six handbooks bound in one. There is, however, some advantage in this combination for the work is primarily designed as a reference book for practising engineers, architects and commercial men, and the interdependence of the diverse matters of the volume is clearly shown by an admirable system of simple cross references.

We venture to question the translator's judgment that the book is "well adapted to home study." Even if it were not so formidable in appearance as to dishearten all but the infatuated and enamoured few, the bravest and most persistent, it is too mature and encyclopedic in style, and too meagre in demonstrations and the logical element generally, for the use of a solitary and unassisted student. It does indeed include most of the mathematical matter prescribed in technological schools for students of engineering and it has commendable regard to the uses and applicabilities of the subject, but it can not be favorably regarded either as an adequate substitute or as a suitable text for the courses now provided in the better institutions. Its logical meagreness has already been pointed out. While it regards mathematics always as a tool and never as a science, it makes little or no provision in the way of exercises for drill work. The point of view maintained throughout is obsolete. In all its pages there is scarcely a hint or suggestion of the critical improvement and illumination that have come to its themes in modern years. There is in it nothing to indicate its limitations, much less to convey a sense of the living and growing character of mathematical science.

All this is not to say that the work is unsound or useless. In general its statements are sound and may be trusted by the practitioner; and it will undoubtedly prove to be exceedingly useful to educated folks whose need exceeds their knowledge of mathematics. The rules and processes of arithmetic extending through common and decimal fractions, the various metric systems, short methods of calculation and numerical approximations, powers and roots, and logarithms with commercial applications, though they are not critically or logically justified, are well ordered, ex-

emplified and explained. The short account of algebra conceives it lightly as "generalized arithmetic," its principles and procedures being loosely derived by analogy. Its main concern is with the question, How — hardly at all with Why. On p. 91 the reader is happily warned against the use of zero as a divisor, but it is not good usage to call $a/0 = \infty$ and $a/\infty = 0$ "general symbols of impossibility," p. 200. The general cubic is solved algebraically, the irreducible case is treated trigonometrically; and graphic and other methods of approximating the real roots of higher numerical equations are given, but no mention is made of Horner, and the student is left to wonder why the method of radicals has been, as it seems, arbitrarily abandoned. The chapter on Geometry is little more than a resumé of the content of ordinary plane and solid geometry. It would not fit a boy to pass the entrance examinations to a good school of engineering. The trigonometry is better, though it has no eye for higher aspects, not looking above or beyond the domain of mensuration, not so much as recognizing the transfiguring touch of Euler's hand or that of de Moivre. If trigonometry is not now, as in the ancient days, literally triangle-measusement, the reader must seek elsewhere for information. The Analytic Geometry is a bare introduction, a brief account of the conics, a few so-called higher curves of the cissoid-spiral set, an excellent section dealing with geometrical construction of algebraic formulas, the notions of evolute, involute and curvature, but no adequate discussion of the general equation of second order or of simple space configurations. The volume closes with a logically easy-going introduction to the differential and integral calculus. We are told that "when Δy and Δx decrease and become infinitely small, the limit is represented by dx and dy," p. 570. In defining integration in terms of summation, no distinction is drawn between sum and a limit of a sum. These indicia sufficiently betray the treatment judged by modern standards. Nevertheless, the student may here learn to perform and to apply the ordinary processes and operations of the calculus; and he may be happier, he will certainly be more confident, for not knowing much of the delicate structure and subtle limitations of the instrument he is employing.

The mechanical and physical make-up of the volume are excellent. And the translator and publisher are alike to be congratulated on their production of a work that many a non-mathematician will use with advantage and satisfaction.

C. J. KEYSER.

Technical Dictionary. Vol. I., Machine Details and Tools. By K. DEINHARDT and A. SCHLOMANN. 12mo., 403 pages. New York, McGraw Publishing Co., 1906. Price, $2.00 net. Illustrated and written in six languages: English, German, French, Russian, Italian and Spanish.

As the title indicates, this book is the first of a series of dictionaries for the assistance of the engineer in reading books and technical papers in foreign tongues. The present volume deals exclusively with the machine elements, small tools and the simple formulas of mechanics. It differs very much from the ordinary technical dictionary in several ways. In the first place it is thoroughly illustrated so that the reader can easily fix in his mind the object and name at once. Again, we find that one can

easily acquire a vocabulary of all pieces in the same class, and also of the parts of which an element is composed. For example in the case of valves; all forms are illustrated together, the names in each language grouped about each illustration; and following each illustration are numbers referring to details about which numbers are grouped the names of the details in the several languages. A very complete single index of all the languages except the Russian, is given so that the book is very usable. The index for the Russian language because of its peculiar alphabet is given separately. There are eleven volumes promised. The other volumes treating of the electric plants and apparatus, steam engines and boilers, hydraulic machinery, hoisting machinery, small tools and machine tools, railways and railway appliances, structural work, metallurgy, architecture, naval construction, etc. While the small size of each volume makes it very handy to use, it is hoped that the large number of volumes will not be the cause of the reader having to look through several indexes before he finds what he wants. For instance, it is noted that in the present volume are found such things as cross-heads, cylinders, connecting-rods, etc., one would also expect to find these in the volume dealing with the steam engine. How this will be taken care of is impossible to say at present. However, the present volume is a very excellent work and reflects much credit on its authors.

It is very substantially bound and the illustrations and printing are very good.

W. R.

Catechism on Producer Gas. By SAMUEL S. WYER, M.E. 12 mo., 42 pages. New York, McGraw Publishing Co., 1906. Price, $1.00 net.

This little book, written by the author of a much larger volume on the same subject, appears to be intended for the general reader as well as for those engineers who desire extremely concise statements rather than critical or exhaustive information. It contains 287 short questions and answers on the elementary physics and chemistry of gases and on the history, status, and technology of producer gas.

H. C. S.

The School of Mines Quarterly.

Journal of Applied Science

VOL. XXXVIII., 1903-7.

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CONTENTS:

Edmund Howd Miller Ph.D., Professor of Analytical Chemistry and Assaying in Columbia University. By Robert Peele 133
The Technical School and the University. By William H. Burr.... 141
North American Index Fossils. II. (continued) By A. W. Grabau and H. W. Shimer 150
Stöber's Method of Making Crystal Drawings. By Austin F. Rogers 222
Abstracts—Analytical Chemistry. By E. Waller 226
Alumni and University News 239
Book Reviews 244

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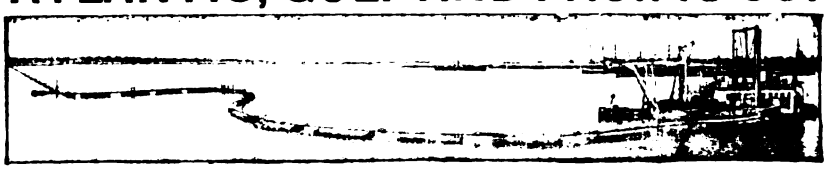

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EDMUND HOWD MILLER.

Died November 8, 1906

ARTOTYPE, E. BIERSTADT, N. Y.

THE

SCHOOL OF MINES QUARTERLY.

VOL. XXVIII. JANUARY, 1906. No. 2.

EDMUND HOWD MILLER, PH.D.

PROFESSOR OF ANALYTICAL CHEMISTRY AND ASSAYING IN COLUMBIA UNIVERSITY.*

The death of Edmund Howd Miller, on the 8th of November last, at Nyack, N. Y., of typhoid fever, abruptly terminated a most useful and promising career, and brought the keenest feeling of personal loss to his friends and associates. Having been seriously ill but a few days it was hard to realize, when the news came that he had passed away, that this strong man's work was ended when he had barely reached middle life. He died at the age of thirty-seven years, respected for his integrity, ability, clear-headedness and firmness of character; loved best by those who knew him most intimately, trusted and relied upon by his colleagues for the soundness of his judgment. Quiet and self-contained, never self-assertive, he had nevertheless come to exert an influence in the direction of his chosen work, which will long be felt.

George Mason Miller, his father, graduated from Columbia College with the degree of A.B., in 1860, having been a classmate of Dean Van Amringe. He afterward received the degrees of LL.B. (1862) and A.M. (1863). During his senior year in the College he took a course in chemistry under Professor Joy, working in a small, improvised laboratory, with a few other students. That he was strongly drawn towards chemistry is shown by the fact that he studied also, for a time, in Professor Bunsen's laboratory, at the University of Göttingen. During the Civil War, having enlisted as a private in the 7th Regiment, N. G. N. Y., he became Captain and afterward Assistant Adjutant-General, U. S. Volun-

* The excellent portrait of Professor Miller on the opposite page has been reproduced from a photograph taken in 1904.

teers. In 1865–6, he was assistant in Assaying in the School of Mines, with Dr. Charles F. Chandler.

Bertha Osgood Miller, the mother of Edmund, is the daughter of the late Dr. Samuel Osgood, who was a graduate of Harvard University and a well-known clergyman and writer. Dr. Osgood was the first president of the Harvard Club, in New York City.

Edmund Howd Miller was born at Fairfield, Connecticut, September 12, 1869. The family residence was in New York until 1881; subsequently a removal was made to Ringwood, N. J., and finally to West Nyack, N. Y., where George M. Miller and family still reside. Edmund Miller received his early education at the Cutler School, New York, where he spent five years. In June 1886 he passed the Harvard examinations, after having studied several years with a tutor, but did not enter that University. Being already interested in chemistry, doubtless an inherited taste, he determined to follow in the footsteps of his father and in 1887 matriculated in the Columbia School of Mines. He took the full four years' course in analytical chemistry, graduating in 1891.

A good student and a hard worker, Miller stood high in his class throughout the four years. Of magnificent physique and unusual muscular strength, he made for himself a record as an athlete. He was specially noteworthy as "anchor" of a famous tug-of-war team, which for two successive years held the intercollegiate and national championships, and for which a gold medal was conferred upon him. His class distinguished him by making him their president.

Immediately after graduation Miller took a position for the summer in the laboratories of Messrs. Ricketts and Banks, also acting as chemist for the Arlington Manufacturing Co. In the fall of 1891 he entered upon his duties as assistant in assaying at the School of Mines. Meantime he continued his studies and received the degrees of A.M. (1892) and Ph.D. (1894). His dissertation for the last-mentioned degree was on Succinimid. The investigation was marked by extraordinary care and involved several new methods of preparation.

During this post-graduate period, and while assistant in assaying, he was a close student and showed marked ability both as teacher and investigator. In 1894 he was appointed to a tutorship in analytical chemistry and assaying, and from that time began to

devote himself chiefly to inorganic chemistry, notwithstanding that the research work done for his doctor's degree had been on the organic side. He was promoted to an instructorship in 1897. Even before this in his unobtrusive way he had won for himself a name and a firm position in the profession, having become well and favorably known in chemical circles for his contributions to the technical journals. He gave much attention during this period to devising and perfecting more accurate methods for the assay and analysis of some of the more important metallic minerals, such as silver, tin, lead and zinc.

On the withdrawal of Dr. P. deP. Ricketts from the department in 1899, Miller was placed in full charge of the quantitative analysis and assaying. In recognition of the value of his work and success as a teacher, he was appointed in 1901 adjunct-professor, and 1904 professor of analytical chemistry and assaying. The management of the courses and laboratory work in qualitative analysis was added to the list of his duties in 1904, so that at the time of his death, he was directing the instruction in all branches of analytical chemistry, comprising the largest division of the School of Chemistry.

Besides covering this wide field of undergraduate instruction, Miller was most painstaking in fulfilling the more difficult function of guiding graduate students in original investigation. He himself actively pursued independent investigations, the most important of which are perhaps those relating to the ferro-, chromi- and cobalticyanides, and to the metals of the platinum group with their alloys. In conducting the research work of post-graduates, his modest and generous nature was frequently evidenced in refusing to allow his name to appear on the printed papers embodying the results, as dividing the honors with the student, according to general custom. The published records of much of his best work are thus to be found under the names of students or associates. He preferred to allow them to have all the credit, even when the entire course of the research had been planned by himself and carried out at his suggestion and under his direction. On other papers his name follows that of the student, instead of preceding it. Dr. Henry C. Sherman has traced a large number of the papers referred to above, published chiefly in the *Journal of the American Chemical Society*, in the years 1898 to 1904, in connection with which Miller's name

does not appear as author. Among the titles of these papers are the following: *

The Determination of Sulphur in Asphalt (1898).

Investigation of Magnetic Iron Ores from Eastern Ontario (1899).

On the Separation and Determination of Arsenic and Antimony in Ores (1899).

On Bismuth Cobalticyanide (1900).

Experiments regarding the Influence of Silica on the Loss of Silver in Scorification (1900).

The Quantitative Separation and Determination of Uranium (1901).

On a Colorimetric Method for the Estimation of Sulphur in Pig Iron (1901).

On the Determination of Manganese in Spiegel (1901).

A Study of the Quantitative Determination of Antimony (1902).

A New Separation of Thorium by Fumaric Acid (1902).

The Gravimetric Determination of Mercury and its Separation from Antimony and Copper (1902).

On the Determination of Lead in Ores (1902).

On the Determination of Sulphur in Coal (1902).

On the Manganese Ferrocyanides (1902).

The Volumetric Determination of Bismuth as Molybdate and its Separation from Copper (1902).

A New Separation of Thorium by Metanitrobenzoic Acid (1904).

Professor Miller was well known as the author of "Calculations of Analytical Chemistry," published in 1900, and a useful condensed work entitled: "Quantitative Analysis for Mining Engineers," 1904. A few weeks before his death he had completed the preparation of a fourth (revised) edition of the "Calculations," the third (1905) edition having been exhausted. He had previously (1897) collaborated with Professor P. deP. Ricketts in a revised and greatly enlarged edition of the latter's "Notes on Assaying." A third edition of this work appeared in 1900. A list of Miller's writings, omitting numerous book reviews, and including the signed papers presented by him to technical journals and societies, is given at the end of this notice.

Not long after graduation Miller was elected a member of the American Chemical Society and soon took a leading part in its

* None of these is included in the list of his signed contributions at the end of this notice.

proceedings, contributing a number of papers. From 1902 to 1904, he served first as vice-chairman, and then chairman, of the New York Section and (ex officio) Vice President of the Society. He was also a member of the following organizations: American Association for the Advancement of Science; American Institute of Mining Engineers; Chemists' Club; member of the executive committee of the New York Section of the Society of Chemical Industry; fellow of the Chemical Society (of London); charter member of the Columbia University Club, in which he served actively for some time on the Committee on Admissions; and member of the Alumni Association of the Schools of Science of Columbia University, acting for two years as one of its Board of Managers. Those who have interested themselves in the Alumni Association will realize that the success which has attended recent meetings is to a considerable degree due to Miller's efforts and his popularity amongst the older as well as the more recent graduates. He was also an honorary member of the Tau Beta Pi Society, a chapter of which was established a few years ago at Columbia. Miller was to have acted as Chairman of the Section on Inorganic Chemistry at the meeting of the American Chemical Society, held in New York during the Christmas holidays just past.

The varied nature of Miller's activities will be realized from the above. He was no less ready to bear his share of administrative work in the University itself. For two years he filled most efficiently the responsible and arduous office of Chairman of the Committee on Admissions of the Schools of Applied Science, and he served well on a number of special committees. He had marked executive ability and took a leading part in the development of the School of Chemistry. In his short life he had become one of the foremost teachers of analytical chemistry. One of his colleagues has said that he had no superior in mineral analysis and but few equals.

On June 11, 1898, at Nanuet, N. Y., Miller married Miss Mary McWhorter. He was extremely happy in his marriage, finding in his wife the inspiration and incentive for his work. Her death, but little more than eighteen months ago (April 17, 1905) was a crushing blow to him. That he never recovered from it was too evident to those friends who were nearest to him and who realized its effects as others perhaps could not. He bore his great loss uncomplainingly and outwardly seemed only to be more quiet

and self-contained than before. While he bravely went on with his duties — even assuming new ones — it was evident to his friends that grief added to over-work had made him a broken man, unable at the last to resist the disease which so quickly took him from us. He left two little children, and is also survived by his father, mother and sister, and a brother, Samuel Osgood Miller, who for some years has been a member of the staff of the Department of Mechanical Engineering.

Miller never ceased to be a student. Although overworked for years in his teaching capacity and by reason of the active and efficient part which he always took in the varied administrative and committee work that devolves on the modern university professor, he still kept abreast of the times in all things relating to general chemistry, as well as the developments constantly in progress in his own particular branches. His reading covered the German and French technical journals and transactions of societies, no less than those published in English. No new development or method escaped him, and he was tireless in searching out the truth of debatable points. Yet he was no "grind"; on the contrary he was of buoyant spirit by nature and an enthusiast over all healthy sports.

As a lecturer Miller was clear, accurate and efficient. He held his students under strict control, at the same time winning their respect by his thoroughness and earnestness, and he had the valuable faculty of instilling a feeling of wholesome fear in the minds of the lazy and incompetent. A serious student never asked his help in vain; he was always ready to give the best he had. In consequence of this trait his own investigative work often suffered. He would spend time freely in studying doubtful points and devising or suggesting means to overcome difficulties. These characteristics were perhaps most marked in his attitude toward post-graduate students who evinced any reasonable degree of capacity. In fixing upon a subject for investigation the practical utility of the end in view was with him a matter of no less importance than the training incident upon the pursuit of that end. He first planned the work and then followed its course closely, lending aid and suggestion in such a way as to gain the confidence of the student and foster his interest and enthusiasm.

Gentleness with firmness, wisdom with modesty and a keen sense of discrimination and appreciation in his friendships — these

were among Edmund Miller's most marked characteristics. He was a man of few words, but clear-headed and candid; slow to form an opinion, careful to think well before expressing a judgment, generous to a fault. All who associated with him obtained justice. It was a remark among the students that "you always get a square deal from Dr. Miller." Throughout his brief but useful professional career, in everything he did, Miller's first consideration was always the welfare of his students and of the university.

ROBERT PEELE.

LIST OF BOOKS AND PAPERS BY EDMUND HOWD MILLER.

(See also list of *unsigned papers*, p. 136.)

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"On the Ferrocyanide of Zinc and Manganese." *Jour. Amer. Chem. Soc.*, Vol. 19, pp. 547–558, 1897.

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"Calculations of Analytical Chemistry." 211 pages, 1900.

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"The Application of Bismuth Ammonium Molybdate to Gravimetric Analysis" (with F. V. D. Cruser). *Jour. Amer. Chem. Soc.*, Vol. 27, pp. 116–121, 1905.

"The New Course for Chemical Engineers at Columbia University." SCH. OF M. QUART., Vol. 26, pp. 267–271, 1905.

"The Insoluble Chromicyanides" (with F. V. D. Cruser). *Jour. Amer. Chem. Soc.*, Vol. 28, pp. 1132–1151, 1906.

"Platinum Silver Alloys" (with J. F. Thompson). *Jour. Amer. Chem. Soc.*, Vol. 28, pp. 1115–1132, 1906.

THE TECHNICAL SCHOOL AND THE UNIVERSITY.

By William H. Burr.

During the past four hundred years there has been a most significant although gradual development in the university organization. This has been a necessary result of the evolution of knowledge. The earliest continental universities found a reason for their being in the dissemination of a system of scholastic learning which had little to do with the affairs of men. A body of learning based chiefly if not wholly upon certain conventional systems of abstract knowledge like the Aristotelian logic, transmitted with little or no change from the masters of antiquity, constituted essentially all they had to offer to their students. The instruction consisted almost entirely of certain exercises in this intellectual inheritance practically unchanged through the centuries of its transmission. This mental training had essentially no relation to or bearing upon the actual things of human experience, nor had it much effect upon national life or upon any of the varied interests of the community.

In the beginning of the sixteenth century however, when the dark shadows of the Middle Ages began to disappear before the illuminating influence of a truer knowledge, a remarkable movement began in a contest which has scarcely been closed to this day. The intense struggle between humanism and scholasticism began in and around the German universities in the early years of the sixteenth century. The actors in this new culture rejected the old sterile instruction with merciless vigor and displaced it with systems of study touching as closely as possible the actual life of those times. It was their open purpose in which they gloried to treat of things as they actually existed, to get as near to the life of the community as the best knowledge would bring them; in other words, to touch human life intimately and at the greatest possible number of points.

Scarcely had the humanistic movement reached a successful issue, before it was supplemented by the Reformation. Although this great religious upheaval was destined ultimately to aid the humanistic movement, an intense struggle marked the first stages

of their concurrent development. While the ultimate effects of these two epoch-making movements were virtually the same in their influence upon the advancement of knowledge and upon the evolution of the university, the fundamentally different characters of their two great representatives led to intellectual contests of exceeding bitterness. Fortunately, however, their efforts to advance knowledge along different lines created a common spirit of true learning, which has been the living stimulant of university life from that day until this.

During the sixteenth and seventeenth centuries the university may be said to have consisted of the philosophical and theological faculties, supplemented by the faculties of law and medicine. The subsequent extensions of the university throughout the eighteenth century resulting from its closer contact with the things disclosed by experience and its widening influence upon all branches of human activity, were chiefly marked by the strengthening of the faculties of law and medicine.

Throughout all this period of over three centuries the philosophical faculty was predominant in its position and influence in the university. It had come to represent a body of more or less abstract instruction covering by far the greater part of the existing field of knowledge, and, it must be said, divorced largely from the real things to which it properly belonged, In the early history of universities it constituted a sort of purveyor of privileged or aristocratic learning ostensibly of better birth than the professional faculties of law and medicine, which had the misfortune to deal with the actualities of life on which the welfare and safety of communities no less than the rights and duties of individuals are fundamentally based. This conventional class distinction constituting a kind of snobbery of learning was the real influence or force so completely overcome by the movements of humanism and the reformation, and it has bequeathed to us the useless and senseless term "pure" science as opposed to applied science; as if there could be in some way a science politely distilled as an essence of learning separated from the realities with which absolutely all science whatever has to deal and without which no science whatever can exist. A scholastic philosophy based upon the sterility of mere convention and authority was displaced by an honest and fearless search for the real knowledge which lies at the base of all true learning. The deadening influence of prescribed knowledge

has given way to the quickening stimulus of individual power and freedom of investigation in every field of human experience. All the professional schools of the university, prominent among them being the modern technical schools, are the fruitful products of this ever increasing and abundant intellectual life.

During the latter part of the eighteenth and throughout the nineteenth centuries the extensions of all branches of physical science so enlarged their fields of application that the foundations were laid of another distinct and prominent faculty. The great investigators in chemistry, in physics, in biology and in the marvelous combinations and ramifications of those and other affiliated sciences were the pioneers in the service rendered by science to the creation of the industries of the world which have been such potent agents in the extraordinary advancement of civilization during the past one hundred and fifty years. Every addition to scientific knowledge, meaning simply a closer contact with the realities of our natural environment, has supplied a corresponding field of activity for useful human effort and in just that much has enlarged the meaning and the volume of life.

All these practical or useful extensions of technical knowledge have in fact been made possible by the technical work of the university, although many of the greatest investigators and of those who have been most successful in enlarging useful production have received their individual stimulus and prosecuted their life work outside of the university organization. The university has been the nursery of useful scientific investigation and the influence of its instruction has extended with an ever increasing acceleration far beyond the limits of its immediate environment. The practice of every technical profession is founded upon precisely that quality and kind of knowledge established by investigation and by instruction at those centers of learning which only have been the originators and transmitters of useful knowledge from the earliest beginnings of science to the present day. Although there has been much scientific investigation and remarkable application of science to human activities by individuals or in communities, to whom apparently even the meaning of university work was unknown, the fundamental principles on which the value of the subsequent technical work is wholly based will be found in practically or absolutely all cases to have germinated in the fertile soil of the university.

The initial stages of technical education took form first in the

universities of Europe. The subsequent development of that educational work into complete technical faculties is found to have been practically concurrent in both the universities of Europe and America, although the former have precedence in time over the latter by comparatively short periods. These faculties have not always been known by the names of the professional practice for which it is the purpose to prepare their students, but the apparent defect in the continuity of the case is not real. In the earliest university courses of technical study instruction was given in a substantial number of technical subjects under a faculty of broader jurisdiction than that confined to a technical profession, and in some of them that method is pursued even at the present time. Such courses of study effectively answered their purpose in the early days of the engineering and allied professions, but their administration has generally been advanced by a natural development concurrent with the growth of the professions which they have served, to remarkable groups of technical faculties of such prominence and intellectual strength and with such numbers of students as almost to dominate the true university in some cases, and even to form essentially technical universities in others.

These great technical faculities have been the direct results of the dissemination of knowledge by the university. Even the professor who has boasted that he never wittingly either learned or taught anything useful has been the servant of real learning by extending the limits of scientific knowledge which refuses to be hindered or circumscribed by its narrowest and most erratic votaries. Wherever there has been a seat of learning, from that point has issued a quickening influence which has stimulated the growth of every form of human industry. All the great industries on which the prosperity of every civilized nation is based, have originally sprung from the small beginnings which had their initial impulse from some branch of knowledge, acquired in the first instance at the university.

So closely are all forms of knowledge related in their fundamental elements that no one of them can attain to a state of real growth without carrying others more or less with it. This elementary principle which finds illustrations and the most conclusive proof in every field of educational experience underlies the fundamental organization of the university, and it completely justifies the place of the technical school in the university plan. Further

than that, it illuminates in a clear and instructive manner the natural development of an institution of universal learning.

The ramifications of every branch of science reach a great variety of human interests many of which are directly affected by it, while others are more remotely touched. The full significance of every acquisition of knowledge can only be understood by realizing the industrial activities or other real interests of the community which it affects. An isolated study of any one technical subject, or of any other subject, without regard to its relation to other branches of knowledge, would be excessively narrow in its results and probably as valueless as narrow, if indeed such a study be not unthinkable. The greater the number and scope of scientific or technical subjects brought within the range of instruction, the broader will be the whole amount of knowledge acquired, and the more complete and thorough will be the comprehension of any one of them. There is a limit to the number of subjects which can profitably be taken by any student in a course of proposed study, but there can be no question whatever that the instruction in any one subject will be enhanced in value in proportion to its breadth, or its reach into other and related or affiliated subjects.

The more complete the view of the field covered, the more satisfactory will be the student's work in it. In fact it may be stated that the real study of any one part of the field of knowledge consists in acquiring information relating to its effect upon other fields into which it reaches. It is impossible to conceive of any subject of scientific study as an abstraction either from other subjects or from the material elements of experience.

The bearing of all these considerations on the place of the technical school in the university is most direct and essential. In the first place the instruction in any professional school of a technical character is an integral part of the whole body of instruction belonging to an institution of universal learning. It cannot be given so effectively anywhere else as in the organization of which it forms a part absolutely necessary for completion.

The advantages gained by a technical school in a university environment are fundamental; they touch both its technical work and the general educational training which must precede the technical in any adequate course of study of a professional character. An engineering or other technical student pursuing his work in a university system finds himself in a stimulating atmosphere of

study and investigation reaching far beyond the limits of his own field. He acquires largely by incidental or even unconscious absorption a broad cultivation by constant contact with active educational work some of which is more or less affiliated with his and some not. This association is an inspiration to a broader and a more enthusiastic view of his own work in itself as well as a material enhancement of value of that work by disclosing its relations to other fields of learning, all impossible to attain outside of the university. These conditions give his educational training qualities which not only strengthen and widen his subsequent professional practice but contribute most effectively to his intelligence and usefulness as an educated citizen.

More than this the technical professions now demand of their members for the higher planes of successful practice the same general educational preparation for professional study as that required by the best law and medical schools. Without entering into a discussion as to the relative merits of the educational work done by the small college and by that forming a subordinate member of the university, it is sufficient to say that this part of a well rounded course of professional study harmonizes completely with the university system and is in fact an essential element of it.

Both for technical efficiency, therefore, and for the broadest and best educational motives the technical school is bound to find its strongest development in an environment of universal study and investigation.

The university has long since lost the character, if it ever properly had it, of a place where abstractions of learning separated from the things which only give them life are to be dispensed after the manner of instruction to men who are never to deal with the affairs of life. It has come to be an intensely practical working agent. It it effective and worthy of support only in so far as it makes itself felt in the real life of the community. If it is to be a true and center of instruction it is imperative that it shall carry knowledge into every useful calling, governmental, corporate, or private. The time will soon come, if indeed it is not already reached, when it only can prepare men to administer and extend in a rational and moral way the great industrial activities which at the present time form the foundation of the material prosperity of the modern world.

The true student of the technical or professional school becomes

heir to a comprehensive and clear understanding of his duties and responsibilities in his relations to his fellowmen and to the community. Those duties and responsibilities present themselves to his trained mind in their real proportion. He is neither non-developed nor mal-developed in his judgment of affairs. His university training, especially in the technical school, has taught him accuracy and penetration in the analysis of any proposition confronting him, and that truth and knowledge must be sought with the directness of a plumb line. Science yields nothing but confusion to the shifty, devious and dishonest inquirer. The fundamentals of morality are the very stepping stones to technical success or professional attainment.

The opportunities offered in the administration of both public affairs and the great corporate interests of the present time, rapidly increasing in number and magnitude, create almost irresistible temptations to prostitute them to selfish gain. The realization that great power, or what has now come to be its full equivalent, great wealth, is a grave and delicate trust, to which selfish gratification in its infinite and seductive variety is abhorrent, comes most naturally and easily through sound knowledge "the beginning of wisdom."

The correct conception of his duties gives to the professional man such a deep and true sense of his responsibilities as to render him the safest administrator of those great interests whose sinister power has already threatened both the morals and the safety of the community. Selfish gratification is a temptation to which he may or may not yield, but his inheritance from the university translates wealth to be a means of accomplishing the highest purposes of life, and saves him from that narrow, common complaisancy of wealth which is the dry rot of character.

In this age of self appointed erratic and dangerous regulators of society when an unreasoning and destructive discontent frequently prompts to crude measures whose real purpose is a blind upheaval of the existing order of things, the intelligence and the calm balance of the university man of affairs must be the corner stones of public safety. His trained mind taught to analyze and to test by the records of experience no less than by the precepts of science does not lose its poise before either the shallow plausibilities of the advocate of Utopia or the sinister deceptions of the revolutionary reformer or what has come to be nearly as bad by the egoistic

and blundering although much applauded strenuosity of the present time.

It is not to be supposed for a moment that every subject of university training will issue from its halls the ideal well rounded citizen, but judgment must be passed upon such matters in view of their resultant tendencies. A fair and careful scrutiny of the impress made through the professional schools of the university from the older faculties of philosophy and theology to the modern faculty of engineering upon the broad, moral, governmental, professional and business affairs of the most civilized communities of the world conclusively confirms and supports these observations.

The creative or evolutionary influence of the university upon the community is exercised chiefly, and it will ultimately be exercised entirely, through its professional faculties, its faculty of philosophy already having become essentially a professional faculty of teaching, a character which it is bound fully to assume hereafter. This is the highest and ultimately the complete mission of the university. This means with absolute certainty that professional instruction shall be given not by closet professors but by men who are students in the highest and best sense of the word, profound students not only of the abstract principles of their profession, but of the play and power of those principles upon the affairs of men. This knowledge must be gained by taking their full part in human experience and not by withdrawing from it. Their investigations must be made largely in the practical operations of their professions. In other words, they must be men of affairs as well as students. A living and forceful quality can be given to instruction in no other way whatever but by actual contact with the things encountered in practical experience and precisely in the relations disclosed by that experience.

Some of the professional faculties have already benefited by this quickening and energizing influence of living contact with their professions. The medical faculties are composed largely of eminent practitioners and it is not too much to say that it would be impossible to give the requisite instruction were it otherwise. It is well known that most serious defects in the present educational admintration of the university faculties of law and engineering are due to the fact that too many instructors fail of that true development and broad training gained only by actual professional experience. It may be confidently stated that instruction in professional

engineering subjects cannot now be given with the necessary breadth and efficiency without supplementing the imperatively necessary work of the study by extended practical experience. And these observations are not peculiar to the faculties to which they are applied. The time has already come when the professional faculties, and preëminently so those of the technical schools, must be active, living parts of their professions. There is no other way by which they can either properly discharge their own functions or become members of a university organization strengthened and equipped to meet its wide educational responsibilities which make it one of the greatest conserving and elevating forces of the community.

The technical schools constituting the great modern professional schools of the university are integral parts of it and necessary consequences of its natural evolution. They belong to it historically and naturally. They are professional schools and professional schools not only belong to the university, they are the university.

NORTH AMERICAN INDEX FOSSILS. II. (CONTINUED.)

By A. W. GRABAU and H. W. SHIMER.*

ATREMATA.

I. Obolella Billings.

Small, thick-valved, oval, with a foraminal opening. Narrow cardinal area on each valve; that on the pedicle valve is crossed by a pedicle groove, not a slit. A long narrow muscular impression is present on each side in the interior of both valves. Shell structure calcareous. Cambric–?Ordovicic.

1. **O. atlantica** Walcott. (Fig. 222, *a–d.*) Lower Cambric.

Resembles *O. crassa* but differs in its average smaller size (⅛–¼ inch long), in its more circular form due to the lesser prominence of the umbo and in its stronger concentric growth lines.

Etcheminian of Massachusetts, Newfoundland.

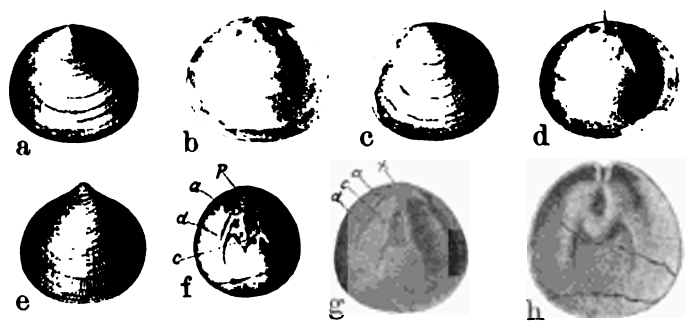

Fig. 222. *a–d, Obolella atlantica; a,* exterior of ventral valve; *b,* mold of interior of same; *c,* exterior of dorsal valve; *d,* mold of interior of same (greatly enlarged); *e–g, Obolella crassa; e,* ventral valve, × 2; *f,* mold of interior of same; *g,* mold of interior of dorsal valve (*a,* cardinal; *c,* central, and *d,* lateral or internal muscular scars; *p,* pedicle groove; *x,* area); *h, Obolella gemma,* interior of a dorsal valve, much enlarged. (All after Walcott.)

2. **O. crassa** (Hall). (Fig. 222, *e–g.*) Lower Cambric.

Sub-orbicular with beaks extending slightly beyond the margin. The two valves are almost indistinguishable from each other; the

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beaks of both are curved down, that of the brachial valve nearly touching the short, indistinct hinge line. Surface of both valves radially and concentrically striated. Shell thick and solid. Average shell is ⅓ inch in length.

Etcheminian of Massachusetts, and Georgian of New York, Quebec.

3. **O. gemma** Billings. (Fig. 222, *h*, 223, *a*, *b*.) Lower Cambric.

Ovate. Pedicle valve with an acute beak. Brachial valve nearly circular and obscurely triangular at beak. Surface of both valves usually nearly smooth or feebly striate. Average length ⅛ inch.

Georgian of New York, Quebec.

4. **O. nitida** Ford. (Fig. 223, *c*.) Lower Cambric.

Brachial valve gently convex. Hinge line slightly curved and equalling about one third the width of the shell. Surface marked by a well defined median depression extending from the most elevated portion of the valve forward for about one half the length of the shell. Valve covered with very fine radiating and concentric striæ. Diameter about ⅛ inch.

Georgian of New York, and Etcheminian of New Brunswick.

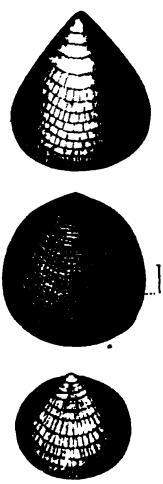

FIG. 223. *a*, *Obolella gemma*, ventral valve, × 6; *b*, dorsal valve, × 6; *c*, *O. nitida*, dorsal valve, × 5. (After Walcott.)

II. DICELLOMUS Hall.

Small, thick-valved, ovate, biconvex with apices marginal. Outer surface of shell finely punctate. Shell substance calcareocorneous. Differs from *Obolella* in the partially corneous character of the shell substance, in the absence of a foraminal opening and in some internal characters. In *Dicellomus* the interior of the pedicle valve shows a short cardinal area with a median pedicle groove, composite muscle scars and a short shelf, like a spondylium extending into the valve from each side of the pedicle groove. The interior of the brachial valve has a narrow cardinal area in one species, *D. politus*. Middle–Upper Cambric.

5. **D. politus** Hall. (Fig. 224.) Middle Cambric.

Valves moderately convex with greatest width near the front which is broadly rounded. Pedicle valve acuminate. Umbos prominent. Cardinal areas in both valves. Surface smooth except for concentric lamellæ.

Mid Cambric of New York, Wisconsin, Minnesota, South Dakota, Montana, Arizona, Oklahoma.

Fig. 224. *Dicellomus politus* exterior natural size, and interior of ventral and dorsel valves much enlarged. (After Hall.)

III. Dinobolus Hall.

Subcircular; valves convex and thick. Pedicle valve with an acute, prolonged beak; cardinal area triangular, deltidium present. Brachial valve with inconspicuous beak. A V-shaped platform, with the apex of the V anterior, extends in each valve from the beak half way to the front; the vaults beneath are more conical than in *Trimerella*. Ordovicic–Siluric.

6. **D. conradi** Hall. (Fig. 225, *a*.) Siluric.

Oval, slightly wider than long and very symmetrical in outline. About 1½ inches wide by 1⅜ inches long.

Niagara of Ohio, Iowa, Illinois, Wisconsin.

IV. Monomorella Billings.

Gibbous. Umbo of pedicle valve more or less elevated with high cardinal area; umbo of brachial valves inconspicuous. Internal platforms of both valves much less prominent than in *Trimerella* and *Dinobolus* and with no empty space beneath; platform of pedicle valve usually continued forward as a strong septum. Siluric.

7. **M. prisca** Billings. (Fig. 225, *b–c*.) Siluric.

Pedicle valve ovate with greatest width at about the anterior third of shell; beak narrowly rounded, front broadly rounded;

septum for about one third the length of shell. Brachial valve about one fourth shorter than the pedicle and more convex with a more broadly rounded anterior portion. Pedicle valve one and a half inches long by a little over an inch wide.

Guelph of Ohio, Illinois, Ontario.

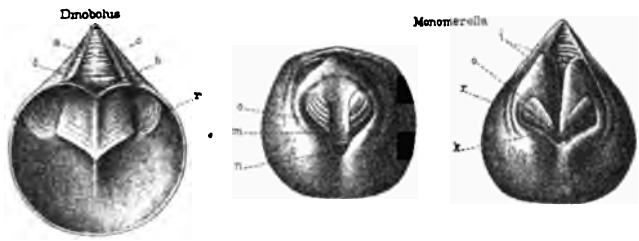

Fig. 225. *a*, *Dinobolus conradi*, interior of pedicle valve, × ⅔ (*a*, deltidium; *b*, deltidial slope; *c*, deltidial ridges; *d*, areal borders; *r*, side of crescent muscular area) *b*, *Monomerella prisca*, internal mold of brachial valve; *c*, internal mold of pedicle valve, × ⅔. (*i*, umbonal chambers; *k*, platform-vaults; *m*, median scars; *n*, anterior scars; *o*, lateral scars; *r*, side of crescent.) (After Hall and Clarke.)

V. TRIMERELLA Billings.

Thick, elongate-ovate. Cardinal area of pedicle valve very prominent; pedicle opening closed by a broad deltidium which is concave owing to the bounding ridges. Brachial valve with no cardinal area but incurved against the deltidium. Long and narrow platforms are present in both valves extending from the apex over half way to the anterior margin; that of the brachial valve is the higher. The area beneath the platforms is occupied by two long, tubular cavities. Most American specimens are internal molds in dolomitic limestone. Siluric.

8. **T. acuminata** Billings. Siluric.

Pedicle valve ovate, widest a little in advance of the middle, tapering from there with nearly straight sides to the beak which is almost acute; the platform bears a deep median furrow. Brachial valve much shorter than the pedicle, more convex and with beak more strongly incurved. Surface marked by coarse concentric growth lines. A very large specimen measures 3½ inches in length by 3 inches in width.

Guelph of Ohio, Illinois, Ontario.

9. **T. ohioensis** Meek. (Fig. 226, *a*, *b*.) Siluric.

Differs from *T. acuminata* in its broader form, and less produced and blunter beak, with thicker septa as indicated by the mold.

In the Niagaran beds of Ohio, Illinois and Ontario.

10. **T. grandis** Billings. (Fig. 224, *c d.*) Siluric.

Ovate, with the greatest width a little in advance of the middle. Both valves moderately and uniformly convex. Surface marked with obscure concentric growth lines. Length of a large shell is 3 inches; width, 2½ inches. This species differs from *T. acumi-*

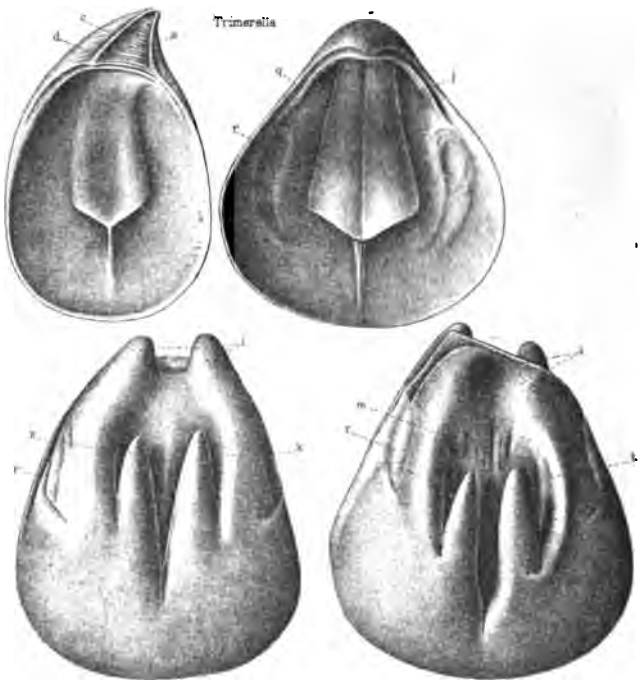

Fig. 226. *a*, *Trimerella ohioensis*, pedicle valve with distorted umbo, × ⅔; *b*. brachial valve, × ⅔; *c*, *Trimerella grandis*, internal mold viewed from brachial side, × ⅔; *d*, the reverse of the same specimen, × ⅔. (*a*, deltidium; *c*, deltidial ridges; *d*, areal borders; *i*, umbonal chambers; *j*, platform; *k*, platform vaults; *m*, median scars; *q*, crown of crescent; *r*, side of crescent.) (After Hall and Clarke.)

nata in that the tubular cavities of the interior do not extend to the beak, the pedicle valve is broader and the concentric lines are obscure.

Guelph of Ohio, Wisconsin, Ontario.

VI. Lingulella Salter.

Valves *Lingula*-like but pedicle valve pointed, with a cardinal area, and elevated beyond the brachial valve; a distinct pedicle groove present. Cambric-Ordovicic.

11. **L. aurora** Hall. Upper Cambric.

Broadly ovate; breadth about ½ inch, length somewhat greater. Pedicle valve with beak slightly attenuate, cardinal area high. Brachial valve with very obtuse beak. Surface marked by concentric striæ crossed in partially exfoliated specimens by radiating striæ.

St. Croix of Wisconsin, Minnesota.

12. **L. (Westonia) ella** (Hall and Whitf.) (Fig. 229. *a*, *b*. Lower-Mid. Cambric.

Brachial valve subcircular or oblate; pedicle valve longer than wide, cardinal slopes about 65 degrees (greater when compressed) area flattened, rather broad and with narrow median groove. Growth lines lamellose towards the front; radiating lines indistinct.

Wasatch and Oquirrh Mountains, Utah; near Pioche, Nevada.

VII. Lingulepis Hall.

Lingula-like but strongly inequivalved. Pedicle valve generally much produced at the beak. Differs from *Lingulella* in the absence of a distinct cardinal area and in the often much attenuated beak of the pedicle valve. Upper Cambric.

FIG. 227. *Lingulepis pinniformis* internal molds of pedicle and brachial valves, ×2. (After Hall.)

13. **L. pinniformis** (Owen). (Fig. 227.) Upper Cambric.

Pedicle valve spatulate; posterior portion attenuate, acute, convex in the middle. Anterior portion semicircular. Brachial valve without the attenuate portion. Surface of both valves marked with concentric striæ and where exfoliated, with faint radiating ones.

St. Croix of Wisconsin, South Dakota. Potsdam of New York and Canada (*L. acuminata*).

14. **L. prima** (Hall.) Upper Cambric.

Valves moderately convex with rounded front. Umbo very low. Surface marked by a few concentric wrinkles and by many fine longitudinal lines. An average shell measures ¼ inch by ⅛ inch in length and breadth respectively.

Potsdam of New York, South Dakota.

VIII. Leptobolus Hall.

Minute with convex valves. Pedicle valve with cardinal area cut by a pedicle groove. Brachial valve slightly thickened on cardinal margin. Interior of both valves with two or three diverging septa. Ordovicic.

15. **L. insignis** Hall. Ordovicic.

Orbicular with a scarcely pointed beak. Valves regularly convex when not compressed. Specimens usually found flattened. Surface marked by concentric growth lines. Differs from *L. occidentalis* in being more nearly circular, with a shorter beak and more regularly convex valves.

Utica of New York, Ohio, Ontario.

16. **L. occidentalis** Hall. Ordovicic.

Widest below the middle. Valves moderately convex and most prominent near the beak. Surface marked by concentric growth lines. About $\frac{8}{100}$ inch in length.

Maquoketa of Iowa and Wisconsin; Lorraine of Ontario.

IX. Lingula Bruguière.

Shell thin, glistening, generally smooth or with fine concentric or rarely radiating striæ; generally equivalved; broad anteriorly, parallel sided or tapering posteriorly. Ordovicic–Recent.

A. Rectangular (sides straight and nearly parallel); hinge extremities abruptly rounded or truncate ..... I.
  I. Surfaces nearly smooth and glossy ..... 22. *L. elderi.*
  I. Surface marked by concentric striæ ..... 1.
    1. Striæ strong, sharp. Shell large ..... *a.*
      a. Radiating striæ absent ..... 24. *L. iowaensis.*
      a. Radiating striæ present ..... 20. *L. rectitateralis.*
    1. Striæ fine ..... *b.*
      b. Striæ crossed by radiating lines ..... 26. *L. clintoni.*
      b. Striæ not crossed by radiating lines ..... 29. *L. cuyahoga.*
B. Oval or elliptical (sides curving) ..... II.
  II. Small, not exceeding one-half inch in length ..... 2.
    2. Length exceeding breadth ..... *c.*
      c. Front subtruncate ..... 32. *L. subspatulata.*
      c. Front broadly rounded ..... †.
        † Beaks attenuate ..... 23. *L. modesta.*
        † Beaks obtuse ..... 27. *L. ligea.*
      c. Front regularly rounded ..... ††.
        †† With flattening and faint radiating striæ ..... 30. *L. melie.*
        †† Convex, without flattening or radiating striæ.. 31. *L. umbonata.*
    2. Length and breadth nearly equal ..... 18. *L. curta.*
  II. Large, 1 inch long ..... 17. *L. cobourgensis.*

C. Wedge-shaped, with very acute beaks ..... III.
III. Valves convex. .... 3.
3. Large ..... 25. *L. cuneata.*
3. Minute..... 28. *L. spatulata.*
III. Valves depressed ..... 19. *L. trentonensis.*
D. With converging but straight sides..... IV.
IV. Beak obtuse, large..... 21. *L. eva.*

17. **L. cobourgensis** Billings (Fig. 228, *a–b.*) Ordovicic.

Large, oval. Both valves moderately convex. Length about one fourth greater than width. Concentric growth lines fine, becoming

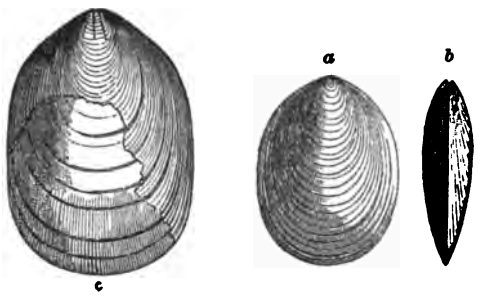

FIG. 228. *a–b, Lingula cobourgensis; c, L. rectilateralis.* All natural size. (After Billings Can. Geol.)

sharp. Elevated and closely crowded striæ on the lateral slopes.

Trenton of Minnesota, southeastern Canada.

18. **L. curta** Conrad. Ordovicic.

Small, obtusely ovate, depressed convex. Length and breadth nearly equal. Beaks scarcely projecting beyond the margin of the shell. Front broadly rounded. Surface covered by elevated concentric lines.

Trenton–Utica of New York, Pennsylvania, Quebec, Frobischer Bay.

19. **L. (Glossina) trentonensis** Conrad. Ordovicic.

Of moderate size, ovate-acute, attenuate toward the apex; sides nearly straight, front rounded. Surface depressed. Smooth or marked by concentric lines which are crossed by obscure radiating striæ.

Trenton and Utica of New York, Wisconsin, Ontario.

20. **L. rectilateralis** Emmons. (Fig. 228, *c.*) Ordovicic.

Large, with nearly parallel sides, form elliptical; front regularly rounded; surface marked by radiating striæ. This species is readily recognized by its large size.

Trenton–Lorraine of New York, Ottawa and Anticosti.

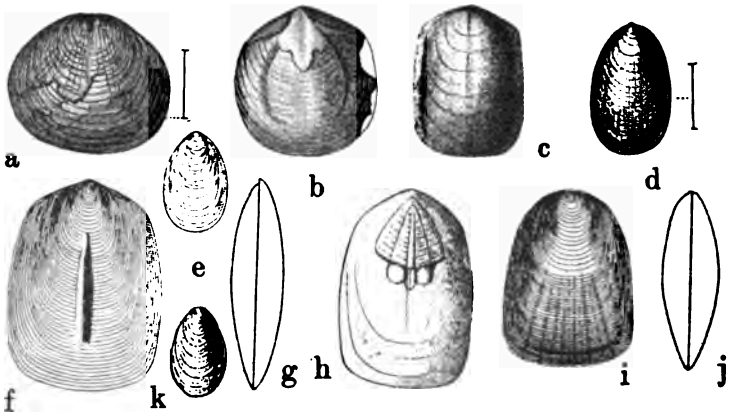

FIG. 229. *a*, *Westonia ella*, × 2; *b*, mold of interior of dorsal valve, × 2; *c*, *Lingula elderi*, dorsal view, × 1; *d*, *L. ligea*, × 2; *e*, *L. modesta*, × 4; *f g h*, *L. iowaensis;* dorsal and profile views, and mold of interior of ventral valve, × 1; *i j*, *L. eva*, dorsal and profile views, × 1; *k*, *L. umbonata*, × 1. (After Walcott (*a*, *b*), Winchell and Schuchert, and Ind. Surv. (*k*).)

21. **L. eva** Billings. (Fig. 229, *i–j*.) Ordovicic.

Widest near the front, with nearly straight gradually converging sides; valves convex, flattened near front; surface with a few prominent radiating striæ on anterior half.

Black River of Canada, Minnesota, etc.

22. **L. elderi** Whitfield. (Figs. 221, 229, *c*.) Ordovicic.

Subquadrangular with nearly parallel margins and subequal extremities, the beak being somewhat angular and the front broadly rounded. Valves quite convex. The dorsal or shorter and more convex valve marked by a flattening along the middle. Surface nearly smooth.

Trenton and Lorraine of Ohio, Wisconsin, Minnesota.

23. **L. modesta** E. O. Ulrich (Fig. 229, *e*.) Ordovicic.

Minute, subovate; widest anteriorly. Valves nearly flat. Anterior third uniformly rounded. Surface marked with very faint concentric undulations.

Trenton-Lorraine of Iowa, Kentucky, Minnesota.

24. **L. iowaensis** Owen. (Fig. 229, *f*, *g*, *h*.) Ordovicic.

Large, broadly subquadrate, generally a little narrower above the middle than below. Beak obscurely angular, front rounded. Sides gently rounded. Valves convex. Beak of pedicle valve projecting a little beyond that of the brachial and more pointed. Surface marked by strong and irregular growth lines.

Galena of Iowa, Illinois, Wisconsin, Minnesota, Manitoba.

25. **L. cuneata** Conrad. (Fig. 230.) Siluric.

Wedge-shaped, very acute at beaks. Margins nearly straight, converging uniformly from beak to front which is but slightly curved (almost truncate). Valves convex on the posterior half but flattened anteriorly. Surface longitudinally striated.

FIG. 230. *Lingula cuneata* enlarged, × 2. (After Hall & Clarke.)

Medina of New York.

26. **L. clintoni** Vanuxem. Siluric.

Sides of shell straight and nearly parallel; abruptly rounded at beak, abruptly truncate at front. Shell flat anteriorly but elevated into a ridge at beak and hence here very convex. Surface marked by concentric growth lines and radiating striae.

Clinton of New York, Pennsylvania, Ontario, Nova Scotia.

27. **L. ligea** Hall (Fig. 229, *d.*) Devonic.

Narrow elliptical with length twice the width. Sides slightly curving. Extremities subequal, with obtuse beak and broadly rounded front. Surface marked by fine concentric striae.

FIG. 231. *Lingula spatulata*, × 2.

Hamilton-Portage of New York, Ohio, Nevada, Ontario.

28. **L. spatulata** Vanuxem. (Fig. 231.) Devonic.

Minute, spatulate, moderately convex; attenuate toward the beak; widest across the middle. Length (scarcely three tenths of an inch) about twice the width. Surface marked by fine concentric striae.

a b

FIG. 232. *a*, *Lingula cuyahoga*, × 1; (after Hall) *b*, *Lingula melie* large specimen, × 2; (Meek.—Ohio Pal.)

Genesee and Portage of New York, Canada, Ohio and elsewhere.

29. **L. cuyahoga** Hall. (Fig. 232, *a.*) Devonic–Lower Carbonic.

Length and breadth about as five to three. Sides nearly parallel, converging slightly toward the cardinal margins. Beak obtuse; front subtruncate. Surface covered by fine concentric striæ.

Chemung–Waverly of New York, Ohio.

30. **L. melie** Hall. (Fig. 232, *b*.) Lower Carbonic.

Generally smaller than preceding, with curving sides and acute beak, below which is a narrow flattened space gradually widening to base. Growth lines crowded at intervals; radiating striæ obscure.

Waverly of Ohio.

31. **L. umbonata** Cox. (Fig. 229, *k*.) Upper Carbonic.

Of medium size, thin, elliptical with regularly rounding margins and prominent umbonal portion. Surface smooth except for lines of growth.

Coal Measures of Kentucky, Ohio, Iowa, and Missourri.

32. **L. subspatulata** Hall and Meek. Upper Cretacic.

Of moderate size, oblong. Lateral margins only slightly curved, narrowing the shell toward the front. Anterior margin subtruncate. Surface marked by fine concentric striæ.

Nebraska, New Mexico, Manitoba.

X. LINGULASMA E. O. Ulrich.

Large, thick-shelled Lingulæ. Brachial valve much the deeper. Muscles of both valves situated upon a platform which extends over one-half the length of the shell; that of the pedicle valve is low; that of the brachial is high and is continued anteriorly as a strong septum. No pedicle opening present. Deltidium present and probably entirely internal, thus forming a sheath resting upon the posterior portion of the pedicle platform. Ordovicic.

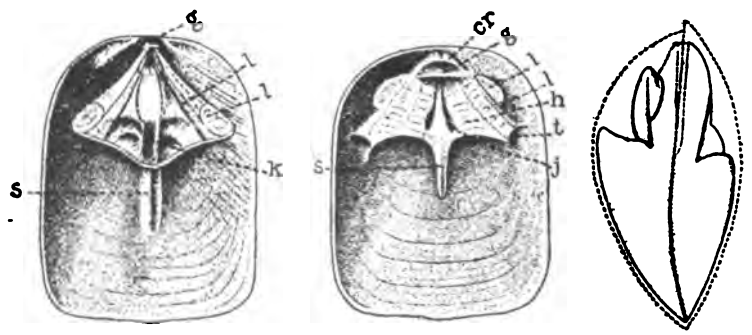

FIG. 233. *Lingulasma galenaense*; interior view of ventral and dorsal valves, and profile of inner mold with outline of shell dotted in (*cr*, crescent; *g*, umbonal scar; *h*, central scars; *j*, anterior scars; *k*, middle scars; *l*, lateral scars; *s*, septum; *t*, transverse scars. × 1.

33. **L. galenaense** Winchell and Schuchert. (Fig. 233.) Ordovicic.

Large, oblong, with nearly straight lateral and anterior margins. Both valves strongly convex. Surface marked with concentric striæ which at irregular intervals rise into small pustules.

Galena of Iowa, Wisconsin, Minnesota.

NEOTREMATA.

XI. ACROTRETA Kutorga.

Pedicle valve subconical with apex truncated by pedicle opening. Posterior margin flattened, triangular and resembling a true cardinal area; this slope is divided medially by a shallow groove widening downward. Brachial valve usually flat. Surface concentrically striated. Differs from *Acrothele* in having the slope from the apex to the posterior margin vertical. Cambric.

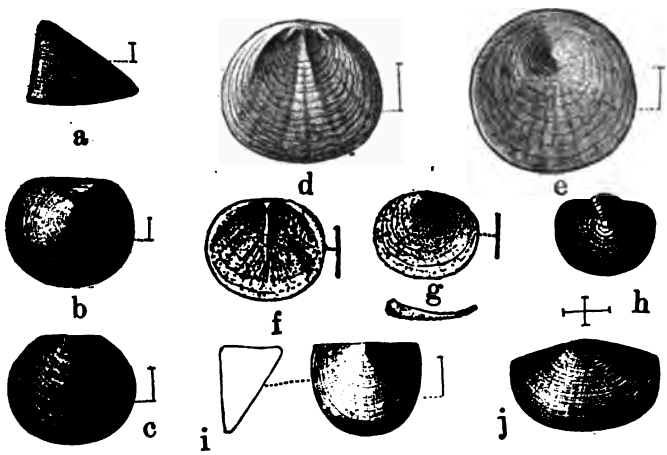

FIG. 234. *a–c, Acrotretra gemma,* side and summit view of dorsal valve, and ventral valve, all × 3; *d, e, Acrothele subsidua,* interior of dorsal and exterior of ventral valves, × 3; *f, g, Acrothele matthewi,* interior, exterior and profile views, × 2; *h, Iphidea bella*; *i, j, Iphidea swantonense,* ventral valve and profile, dorsal valve. (*f* and *g* after Matthew, the others after Walcott.)

34. **A. gemma** Billings. (Fig. 234, *a–c.*) Lower to Upper Cambric.

Minute. Brachial valve circular and nearly flat with beak not projecting beyond the hinge line and with wide, shallow mesial sinus. Pedicle valve acutely conical with flat triangular area whose base forms half the width of the shell.

Montana, Utah, Nevada, Newfoundland.

XII. Acrothele Linnarsson.

Corneous, subcircular. Pedicle valve subconical with excentric beak truncated by the pedicle opening, anterior to which are often two wart-like protuberances. Two such protuberances also form the umbo of the brachial valve which is marginal. Differs from *Acrotreta* in having the slope from the apex to the posterior margin quite gentle, and in the absence of a cardinal area. Cambric.

35. **A. matthewi** (Hartt). (Fig. 234, *f–g.*) Middle Cambric.

Round, extremely flat and thin. The two small wart-like protuberances are present in front of the foramen of the pedicle valve.

St. John beds of Newfoundland, New Brunswick.

36. **A. subsidua** (White). (Fig. 234, *d–e.*) Lower to Middle Cambric.

Thin, with transverse diameter slightly exceeding the longitudinal. Sides regularly and front broadly rounded. Posterior margin forms a short and nearly straight hinge line. Brachial valve flat; pedicle valve somewhat convex near the umbo, with rather prominent beak.

Utah, Nevada.

37. **A. gamagei** (Hobbs). Middle Cambric.

Differs from *A. matthewi* in its more nearly circular form, longer hinge-line and in having the surface marked by radiating striæ. Surface flat or slightly convex instead of concave in anterior portion.

Middle Cambric Paradoxides beds of eastern Massachusetts.

XIII. Linnarssonia Walcott.

Calcareous, subcircular, convex. Beak of pedicle valve excentric, perforated by a minute pedicle opening. No cardinal area on either valve. Differs from *Obolella* in the absence of the great lateral muscular impressions and cardinal areas, and also in the presence of a pedicle opening in the pedicle valve. It is smaller and more conical than *Acrothele*. Cambric.

38. **L. pretiosa** (Billings). Upper Cambric.

Breadth exceeding length with greatest width about the middle. Beaks very obtuse. Surface covered with very fine lamellose concentric striæ. Length about ¼ inch.

Quebec.

XIV. Iphidea Billings.

Pedicle valve subconical, strongly elevated at beak; flattened posteriorly, forming an appearance resembling a true cardinal area; this area is crossed by a broad triangular ridge (deltidium). Hinge line nearly straight. Beak excentric, perforated by the pedicle opening. Brachial valve semicircular, slightly convex. Surface of shell covered with fine concentric striæ. The possession of the large convex deltidium distinguishes it from *Acrotreta*. Cambric.

39. **I. bella** Billings (Fig. 234, *h*.) Lower Cambric.

Small and conical. Pedicle valve about ½ inch wide by slightly less long. Surface covered with fine concentric striæ which are continued across the large flat area. These striæ are crossed by a few obscure radiating ones.

Massachusetts, Quebec, Labrador.

40. **I. pannulus** (White). Lower and Middle Cambric.

Differs from *I. bella* in its smaller size (⅛ inch) and in the character of the surface markings; these consist of a fine network of oblique, raised lines, visible under a lens.

New York, Utah, Nevada, Quebec, British Columbia.

41. **I. swantonense** Walcott. (Fig. 234, *i–j*.) Lower Cambric.

Hemispheric to semioval outline with high hinge area, marking the greatest width of the shell and surface marked by concentric growth lines. (This is also known under the name *Paterina labradorica*.)

Georgian of Swanton and Highgate Springs, Vermont.

XV. Trematis Sharpe.

Subcircular. Pedicle valve unevenly convex, depressed in posterior portion. The margin of the pedicle valve is interrupted by the pedicle fissure which extends almost to the subcentral apex; internally the sides of this fissure are often thickened. Brachial valve convex; apex marginal or slightly projecting. In interior of pedicle valve radiating sinuses extend from the apex. Surface of both valves covered with punctures which are arranged either in quincunxial order or in radiating rows and penetrate the outer calcareous layers of the shell, but not the inner corneous ones. Ordovicic.

42. **T. ottawaensis** Billings. (Fig. 235, *c.*) Ordovicic.

About one inch in diameter. Surface covered with fine radiating striæ and crossed concentrically by fine discontinuous ridges.

Trenton and Lorraine of New York, Kentucky, Minnesota, Ontario, Anticosti.

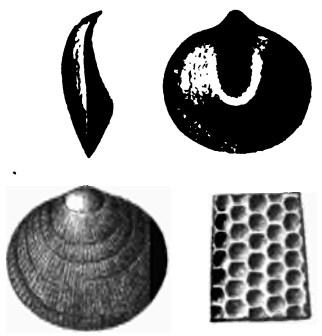

FIG. 235. *a*, *b* and *d*, *Trematis millipunctata*, profile and ventral view, × ⅔ and enlargement of surface, × 16; *c*, *Trematis ottawaensis*, brachial valve, × ⅔. (After Hall and Clarke.)

43. **T. terminalis** Emmons. Ordovicic.

About half as large as the preceding or smaller; foraminal slit flanked by broad depression. Apex of brachial valve marginal, not projecting.

Trenton of New York and Canada.

44. **T. millepunctata** Hall. (Fig. 235, *a–b*, *d.*) Ordovicic.

Intermediate in size between the two preceding; foraminal slit deep, beak of brachial valve projecting. Surface punctate.

From the Utica and Lorraine of Cincinnati, O., and Covington, Ky.

XVI. SCHIZOCRANIA Hall and Whitfield.

Subcircular, strongly inequivalve. Pedicle or lower valve flat or concave; a deep, broad triangular notch extends from near the subcentral beak to the margin where it constitutes about one sixth of the periphery. In the apex of this notch is a triangular transverse plate extending about one third the distance to the margin. Surface covered with concentric lines. Brachial valve convex; larger than the pedicle valve and extending beyond it on all sides. Beak marginal or submarginal. Surface with radiating striæ. Ordovicic and Devonic.

45. **S. filosa** Hall. (Fig. 236, *a.*) Ordovicic.

Slightly ovate. Surface of brachial or upper valve covered with fine, even radiating striæ. Pedicle valve strongly marked by irregular concentric undulations. This species is usually found attached to brachiopods, particularly to *Rafinesquina alternata*.

Trenton–Lorraine of New York, Ohio, Minnesota, Ontario.

XVII. LINGULODISCINA Whitfield.

Upper (brachial) valve linguloid with nearly terminal beak in typical species; lower (pedicle) valve discinoid with centrally placed

beak. Much like *Schizocrania* but the brachial valve has no radiating striæ. Pedicle area much elevated internally and cut by a narrow, open fissure. Devonic–Lower Carbonic.

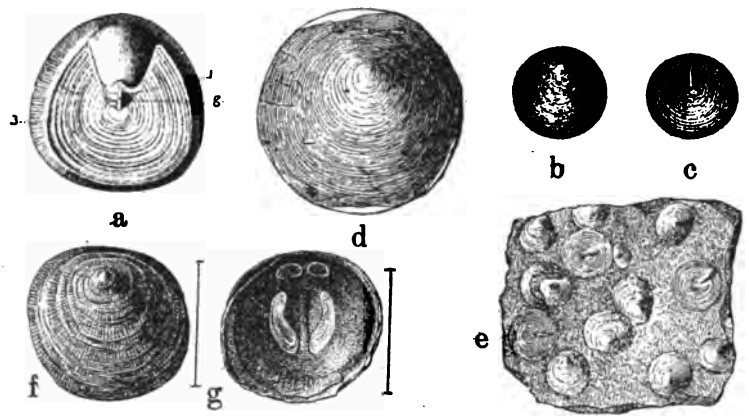

FIG. 236. *a*, *Schizocrania filosa*, × 2, specimen with dorsal or upper valve partly removed, only the margin remaining (*B*) and showing interior of ventral valve (*P*), showing broad notch and pedicle groove *g*; *l*, walls of groove (Winchell & Schuchert); *b*, *c*, *Lingulodiscina newberryi*, dorsal and ventral valves, × 1 (Ohio Pal.); *d*, *Orbiculoidea convexa*, dorsal valve, × 1; *e*, *Orbiculoidea missouriensis*, × 1, (Ind. Survey); *f*, *g*, *Discinisca lugubris*, exterior and interior of dorsal valve, × 1 (Md. Surv).

46. **L. newberryi** (Hall). (Fig. 236, *b*, *c*.) Lower Carbonic.

Brachial valve with prominent apex situated near the posterior margin. Pedicle valve slightly concave with excentric apex and large oval foramen with deeply depressed margins. Shell thick, strong and of a lamellose structure. Surface marked by fine concentric lines.

Waverly of Ohio, Nevada.

XVIII. SCHIZOBOLUS Ulrich.

Oval, depressed convex. Apex of pedicle valve at terminus of a rather deep notch in the posterior margin; apex of brachial valve subterminal and but slightly elevated with no notch present. Each valve with a pair of muscle impressions situated posteriorly and separated by a median ridge extending about one third the distance to the front of the shell. Devonic.

47. **S. concentricus** (Vanuxem). (*S. truncatus* Hall.) (Fig. 237.) Devonic.

Very small, rarely exceeding one fifth inch in length. Broader

anteriorly and with posterior margin abruptly rounded or truncate. Surface marked by fine concentric striæ and with faint radiating lines. The brachial valve somewhat resembles a *Lingula*.

Genesee and Naples of New York, Kentucky, Indiana.

FIG. 237. *Shizobolus concentricus*, interior of pedicle and brachial valves and exterior of pedicle valve, × 2.

XIX. ORBICULOIDEA d'Orbigny.

Corneous, subcircular. Apices excentric. Pedicel valve with a narrow pedicle groove beneath the beak extending almost to the margin of the valve; just behind the beak this groove penetrates through a long tube obliquely to the interior of the valve where it opens near the margin; in this it differs from *Discinisca*. Brachial valve larger, depressed conical. Ordovicic–Carbonic.

48. **O. lamellosa** Hall. Ordovicic.

Apex nearly central. Surface covered with rather strong sublamellose concentric growth lines which become more distinct and coarser from the apex outward.

Trenton and Lorraine of New York, Minnesota, Ontario.

FIG. 238. *Orbiculoidea lodiensis*, dorsal valve, × 2.

49. **O. lodiensis** Vanuxem. (Fig. 238.) Devonic.

Small, rarely exceeding one-third inch in diameter. Brachial valve with minute apex. Pedicle valve somewhat abruptly elevated at apex, with linear foramen. Surface covered with fine concentric striæ and on the anterior half of the shell with faint radiating folds or undulations.

Genesee of New York, Nevada.

50. **O. convexa** (Shumard). (Fig. 236, *d*.) Upper Carbonic.

Pedicle valve broadly convex with height nearly equal to one half the diameter; apex moderately prominent, situated at about one third the distance from the posterior margin. Surface marked by distinct concentric growth lines. Diameter about one inch.

Ohio, Indiana, Missouri, Kansas.

51. **O. missouriensis** Shumard. (Fig. 236, *e*.) Upper Carbonic.

Small, averaging about one fourth inch in diameter. Apex

prominent. Surfaces of both valves marked by concentric lines and fine lamellations.

Ohio, Indiana, Iowa, Illinois, Missouri.

XX. Discinisca Dall.

Lower pedicle valve flattened or concave with an elevated interior pedicle disc perforated by an oval pedicle opening which passes directly through the shell; externally this pedicle disc shows as a depressed area. Upper or brachial valve convex. Apices of both valves nearly posterior. Shell structure more or less horny. Miocenic and Pliocenic.

52. **D. lugubris** Conrad. (Fig. 236, *f–g*.) Miocenic and Pliocenic.

Small (about ½ inch in diameter), subcircular. Brachial valve with rather elevated apex which is obtusely pointed and situated at about one fourth the shell's diameter from the posterior margin. Surface strongly lamellose especially over the outer half. Very faint radiating lines are visible.

New Jersey, Maryland, Virginia, South Carolina.

XXI. Schizotreta Kutorga.

Similar to *Orbiculoidea* but with thicker shell and with the relative convexity of the valves reversed, *i. e.*, the pedicle valve very convex and the brachial flattened. Ordovicic–Siluric.

53. **S. pelopea** Billings. (Fig. 241, *a–b*.) Ordovicic.

Nearly circular with strongly elevated pedicle valve and depressed convex brachial valve. Surface marked by numerous strongly elevated concentric lines of growth. Pedicle opening small oval.

Trenton and Lorraine of Iowa, Wisconsin, Minnesota, Ontario, Quebec.

54. **S. tenuilamellata** (Hall). Siluric.

Shell thin, larger and more circular than preceding with thin, elevated, prominent, concentric lamellose growth lines; pedicle valve elevated with foraminal slope concave, and elongate external pedicle opening.

Niagara beds of New York, Ontario, and Nova Scotia.

XXII. Rœmerella Hall and Clarke.

Similar to *Orbiculoidea* but with pedicle valve very concave and brachial very convex. Devonic.

55. **R. grandis** Vanuxem. (Fig. 239.) Devonic.

Large, broadly elliptical. The direction of the foramen in the pedicle valve is in the shorter diameter of the shell.

Hamilton of New York, Ohio, Indiana, Kentucky.

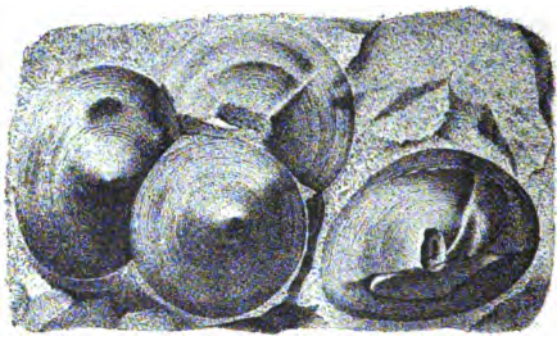

FIG. 239. *Roemerella grandis*, a group of dorsal and ventral valves, × 1. (After Hall.)

XXIII. CRANIA Retzius.

Nearly circular, inequivalved, with no pedicle opening but attached by apex or by the entire surface of the pedicle (lower) valve which is depressed, conforming to the surface to which it is attached. Brachial (upper) valve conical with subcentral and posteriorly directed beak. In each valve is a pair of widely separated muscle scars near the posterior margin and a pair close together near the center, vascular sinuses digitate. Middle Cambric–Carbonic.

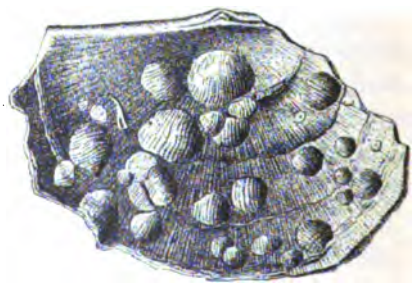

FIG. 240. *Crania scabiosa*, a number of shells attached to a brachial valve of *Rafinesquina alternata*, the ornamentation of which they adopt, × 1. (After Hall and Clarke.)

56. **C. scabiosa** Hall. (Fig. 240.) Ordovicic.

Small with irregular outline and thickened margins. Brachial valve thin. Surface of both valves usually marked by strongly lamellose growth lines. Found adhering to brachiopods and sometimes unrecognizable because of their assuming the surface features of the body to which they are attached. Differs from *C. modesta* in that the average shell is larger and more rugose.

Utica and Lorraine of Ohio, Indiana, Illinois, Wisconsin.

57. **C. setigera** Hall. (Fig. 241, *e–f.*) Ordovicic.

Small; often with nearly straight cardinal margin. Surface marked with quite coarse pustules or setæ which are most distinct near the margin of the shell.

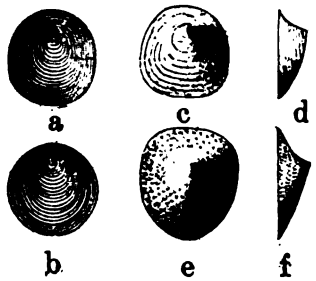

FIG. 241. *b*, *Schizotreta pelopea*, dorsal and ventral valves, the latter showing small oval pedicle opening; *c*, *d*, *Crania trentonensis*, dorsal and profile views; *e*, *f Crania setigera*, dorsal and profile views. (After Winchell and Schuchert.)

Trenton and Lorraine of Iowa, Illinois, Wisconsin, Minnesota.

58. **C. trentonensis** Hall. (Fig. 241, *c–d.*) Ordovicic.

Brachial valve thick, thus differing from *C. scabiosa* and not covered as in *C. setigera* with elongate pustules.

Trenton of New York, Illinois, Wisconsin, Minnesota.

59. **C. lælia** Hall. (Fig. 242.) Ordovicic.

Small, moderately convex, apex of upper valve distant from margin one third diameter of shell; surface with fine sharp striæ, increased sometimes by implantation.

Utica to Lorraine of Ohio and Indiana.

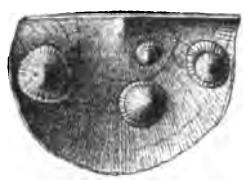

FIG. 242. *Crania lælia*, four individuals attached to shell of *Strophomena planumbona*, × 1. (After Hall and Clarke.)

FIG. 243. *Crania crenistriata*, lateral and top views of an elliptical dorsal valve, × 1. (After Hall.)

60. **C. crenistriata** Hall. (Fig. 243.) Devonic.

Brachial valve depressed conical. Surface marked by elevated, crenulate radiating striæ which reach nearly to the smooth apex.

Onondaga and Hamilton of New York, Ohio, Kentucky, Michigan.

61. **C. modesta** White and St. John. (Fig. 466, *d.*)
Upper Carbonic.

Average diameter ½ inch. Brachial valve moderately convex. Surface concentrically striated.

Ohio, Indiana, Iowa, Kansas.

XXIV. Craniella Œhlert.

Large, subcircular or subquadrangular. Pedicle (lower) valve thin, adhering by its entire surface. Brachial (upper) valve conical with subcentral and posteriorly directed apex. Muscle scars similar to *Crania*. Differs from *Crania* in the vascular sinuses of

Fig. 244. *1, 2, Craniella hamiltoniæ*, top and lateral view of dorsal valve; *3*, a group of ventral valves attached to shell of *Cypricardella bellistriata*, × 1. (After Hall.)

the brachial valve being S-shaped; they start from near the posterior muscle scars and extend to the anterior portion of the valve, sending to the sides of the valve dichotomizing secondary branches. Ordovicic–Devonic.

62. **C. hamiltoniæ** Hall. (Fig. 244.) Devonic.

Subcircular. Brachial valve nearly conical with subcentral apex, pointed in well preserved specimens. Exterior marked by concentric lamellose striæ. Pedicle valve marked by four strong adductor muscle impressions and by digitate vascular impressions.

Hamilton of New York; Hay and Athabasca rivers, Canada.

XXV. Pholidops Hall.

Small, ovate, unattached, equivalved and equiconvex; without pedicle opening. The edges of the valves are flattened where they join. The interior of each valve is marked by an elevated and sharply defined muscular impression which is subtriangular with the apex of the triangle pointing anteriorly. Ordovicic–Devonic.

63. **P. hamiltoniæ** Hall. (Fig. 245.) Devonic.

Ovate with broader posterior end. Apex excentric and inclined backward. Surface marked by closely arranged lamellose growth lines.

Hamilton of New York.

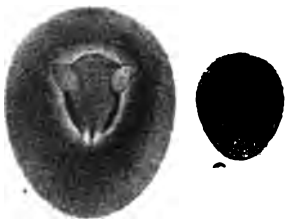

FIG. 245. *Pholidops hamiltoniæ*, interior, × 8, and exterior, × 4. (After Hall.)

PROTREMATA.

XXVI. KUTORGINA Billings.

Inequivalved; hinge line nearly equal to the greatest width of the shell. Larger or pedicle valve usually much more convex than the brachial; umbo straight or incurved; median sinus present or absent. Each valve with a relatively large and broad pedicle opening. Surface covered with concentric growth lines. Interior marked with muscle scars radiating from the beak. Lower–Middle Cambric.

64. **K. cingulata** Billings. (Fig. 246.) Lower Cambric.

Pedicle valve convex, arching over to the incurved and pointed beak; mesial sinus often present. Brachial valve depressed, with

FIG. 246. *Kutorgina cingulata*, ventral, profile and dorsal views, denuded mostly of outer surface. (After Walcott.)

elevated but not incurved beak. Surface covered with coarse striæ and in older portions with undulations of growth.

Vermont, Quebec, Labrador.

XXVII. DICTYONELLA Hall.

Subtriangular, biconvex. Pedicle valve with a broad median sinus and acute and arched umbo. Delthyrium closed by a depressed plate. Brachial valve with a broad median fold; median septum high. Exterior surface pitted with quincunx, resembling *Trematis*. Siluric.

65. **D. reticulata** Hall. (Fig. 247.) Siluric.

Shell gibbous posteriorly and more attenuate in front. Pedicle valve with small, acute and closely incurved beak which is flattened on the back, forming the "depressed plate."

Niagara of Ohio, Indiana, Wisconsin.

FIG. 247. *Dictyonella reticulata*, dorsal and cardinal views, × 2. (After Hall.)

FIG. 248. *Billingsella coloradoense*, dorsal and ventral valves, natural size. (After Hall.)

FIG. 249. *Nisusia festinata*. (After Walcott.)

XXVIII. BILLINGSELLA Hall and Clarke.

Small, subquadrate or semicircular; hinge line straight. Pedicle valve the larger and convex; cardinal area moderately high, vertical or but slightly incurved, with a strong, arching deltidium. Brachial valve flat or concave; cardinal area lower than in pedicle valve but usually also possessing a convex deltidium. Dental plates continued along the bottom of the valve enclosing a small muscular area near the apex. Entire surface covered with radiating plications. Cambric–Siluric.

66. **B. coloradoensis** (Shumard). (Fig. 248.) Upper Cambric.

Differs externally from *Protorthis billingsi* in being less transverse and in that the brachial valve lacks both sinus and cardinal area.

From Texas to Missouri, Minnesota, Wisconsin, Montana, Wyoming and Idaho.

XXIX. NISUSIA Walcott.

Differs from *Billingsella* in that the radiating ribs support irregularly distributed spines on their crests; and in the presence of a mesial sinus on the pedicle valve and a faint mesial fold on the brachial. Lower-Middle Cambric.

67. **N. festinata** Billings. (Fig. 249.) Lower Cambric.

Hinge line straight, usually equalling the greatest width of the shell. Pedicle valve elevated at the umbo with a high cardinal area. Surface covered with narrow radiating ribs, increasing both by bifurcation and intercalation. The spines are located on the ribs more or less irregularly. An average shell measures about one inch in width with length about one third less.

New York, Pennsylvania, Vermont, Quebec.

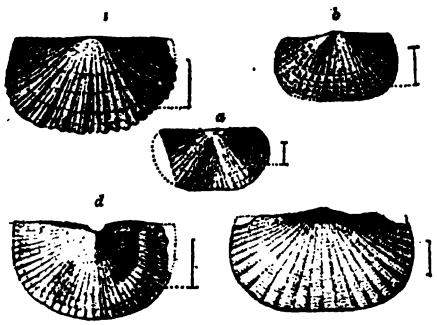

FIG. 250. *Protorthis billingsi*, showing variation of form. (Dawson and Walcott.)

XXX. PROTORTHIS Hall and Clarke.

Middle-Upper Cambric.

Like *Billingsella* but differing in the absence of a true cardinal process and in the punctate character of the shell substance.

68. **P. (Billingsella) billingsi** (Hartt). (Fig. 250.) Middle Cambric.

Broader than long with greatest width at hinge line. Most convex at about the middle and depressed in front. Brachial valve with sinus. Cardinal area very narrow. Surface marked by about thirty radiating striae crossed by distinct lines of growth.

New Brunswick.

XXXI. RAFINESQUINA Hall and Clarke.

Semi-oval; hinge line straight; cardinal area well developed on each valve. Pedicle valve convex; brachial concave. Muscular area of pedicle valve faintly delimited, consisting of two broad, flabellate diductor scars enclosing an elongate adductor; from the margin of the muscular area radiate irregular furrows and nodose ridges. Brachial valve with bilobed cardinal process. Entire surface covered with striae alternating in size and crosed by finer concentric growth lines. Ordovicic-Siluric.

69. **R. alternata** (Emmons). (Fig. 251.) Ordovicic.

Broadly semi-oval. Pedicle valve convex, flattened near the

cardinal extremities. Alternation of striæ very pronounced on both valves.

Trenton-Lorraine of New York, Ohio, Indiana, Illinois, Missouri, Wisconsin, Minnesota, Manitoba, Anticosti.

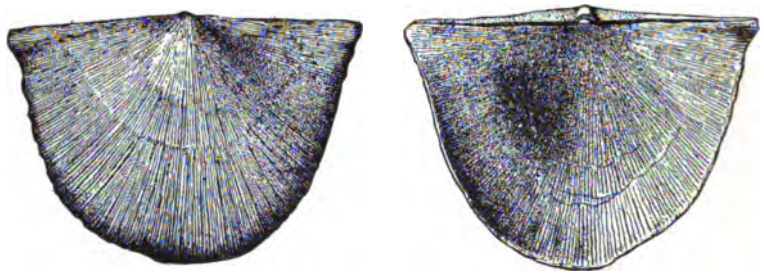

FIG. 251. *Rafinesquina alternata*, ventral and dorsal views, × 1. (Ind. Geol. Survey.)

70. **R. deltoidea** (Conrad.) Ordovicic.

Pedicle valve abruptly deflected at the margin except a small portion in front. Surface of the valve before deflection covered with many irregular concentric wrinkles crossed by radiating striæ which, with the exception of one or two prominent ones in the middle of the shell, are equal. Can be distinguished externally from *Leptæna rhomboidalis* by its usually deltoid outline and by the lesser prominence of its corrugations.

Trenton and Utica of New York, Iowa, Missouri, Wisconsin, Minnesota, Ontario, Manitoba.

71. **R. minnesotaensis** (N. H. Winchell). (Fig. 252.) Ordovicic.

Very similar to *R. alternata* in form and surface features but usually distinguishable by its smaller size and greater convexity.

Trenton of Kentucky, Tennessee, Iowa, Wisconsin, Minnesota.

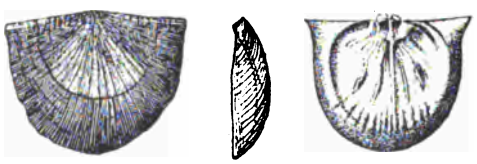

FIG. 252. *Rafinesquina minnesotaensis* (var. *inquassa*), ventral and profile views of a shell, and interior of brachial valve, × 1. (Min. Geol. Survey.)

XXXII. STROPHEODONTA Hall.

Very similar to *Rafinesquina* but with cardinal margins finely denticulate, *i. e.*, marked by transverse bars which articulate as teeth and pits. Shell structure coarsely punctate. Siluric–Devonic.

A. Shell with radiating plications..... 83. *S. costata.*
B. Shell with radiating striæ..... *.
* Shell nearly flat..... (1).
(1) Surface with prominent concentric wrinkles ..... 75. *S. beckei.*
(1) Surface with only oblique folds at the hinge margin... 72. *S. corrugata.*
(1) Surface with very slight concentric wrinkles or none..... *a.*
a. Shell very thin. Striæ usually wavy..... 85. *S. perplana.*
a. Shell thin. Striæ straight..... 74. *S. varistriata.*
* Shell quite concavo-convex ..... (2).
(2) Shell large (about 1½ inches long or longer)..... *b.*
b. Hinge extremities rounded..... 76. *S magnifica.*
b. Hinge line usually extended ..... †.
† Strong concentric striæ present, crossing the finer striæ. 78. *S. patersoni.*
† Strong concentric striæ absent ..... ‡.
‡ Shell conspicuously concavo-convex ..... *x.*
x Pedicle valve with greatest convexity near the front. *aa.*
aa. Striæ alternating..... 81. *S. concava.*
aa. Striæ not alternating..... 80. *S. hemispherica.*
x. Pedicle valve with greatest convexity in the umbonal region..... 77. *S. magniventer.*
x. Pedicle valve regularly convex from beak to front. 73. *S. profunda.*
‡ Shell slightly convex to flat..... 74. *S. varistriata.*
(2) Shell small (about 1 inch long)..... *c.*
c. Radiating striæ strongest near the beak..... 84. *S. demissa.*
c. Radiating striæ not strongest near the beak..... 79. *S. inequiradiata.*
(2) Shell very small (about ½ inch long)..... *d.*
d. Hinge line extended..... 82. *S. inequistriata.*
d. Hinge line less than greatest width of shell..... 86. *S. arcuata.*

72. **S. corrugata** (Conrad.) (Fig. 253.) Siluric.

Small, nearly flat ; hinge line extended. Surface covered with fine prominent striæ. Oblique folds present on the hinge margin. Clinton of New York, Tennessee.

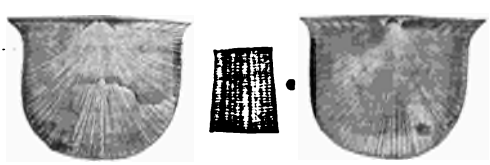

FIG. 253. *Stropheodonta corrugata*, with surface enlarged.

73. **S. profunda** Hall. (Fig. 254.) Siluric.

Large with width much greater than the length. Brachial valve very concave with abruptly deflected margins. Surface covered with fine unequal striæ.

Clinton and Niagara of New York, Kentucky, Indiana, Illinois, Wisconsin.

FIG. 254. *Stropheodonta profunda*, with enlargement of striæ.

74. **S. varistriata** (Conrad). (Fig. 255.) Siluric-Devonic.

Pedicle valve varying from slightly convex to gibbous, with slightly elevated beak. Surface usually with alternations of more or less prominent striæ the sharper ones being separated by several minute ones.

Manlius and Coeymans of New York, Quebec, New Brunswick.

FIG. 255. *Stropheodonta varistriata.*

FIG. 256. *Stropheodonta* (*Leptostrophia*) *beckei*, interior and exterior of pedicle valves of different sizes; profile of complete shell.

75. **S. (Leptostrophia) beckei** Hall. (Fig. 256.) Devonic.

Pedicle valve very depressed convex with small beak. Brachial valve nearly flat. Surface marked with strong, close, bifurcating striæ which are crossed by fine concentric lines and by more or less regular concentric wrinkles. In its surface characters it thus much resembles *Leptæna rhomboidalis* but differs in being almost flat.

Helderbergian of New York, Kennedy Channel of the Arctic region.

76. **S. (Leptostrophia) magnifica** Hall. (Fig. 257.) Devonic.

Very large with rounded hinge extremities. Pedicle valve depressed convex at the umbo; brachial valve slightly concave.

FIG. 257. *Stropheodonta* (*Leptostrophia*) *magnifica*, pedicle valve partly removed and showing impressions of inner structures; interior of brachial valve.

Radiating striæ rather faint and regularly bifurcating two or three times.

Oriskany of New York, Maryland, Ontario.

77. **S. magniventer** Hall. Devonic.

Length usually ⅔ the breadth. Pedicle valve convex in the umbonal region with slightly incurved beak. Hinge line sometimes extended. Radiating striæ regular and slightly elevated.

Oriskany of New York, Ontario, Quebec.

78. **S. patersoni** Hall. (Fig. 258.) Devonic.

Convex. Distinguished by its form, the pedicle valve being gibbous just in the middle and somewhat deeply deflected at the

sides and front. The striæ are distant and elevated with many finer ones between. Strong wrinkles cross concentrically over the fine striæ, being interrupted by the larger ones.

Oriskany–Onondaga of New York, Ohio, Illinois, Nevada, Ontario.

FIG. 258. *Stropheodonta patersoni*, pedicle valve. (After Hall.)

79. **S. inæquiradiata** Hall. (Fig. 259.) Devonic.

Pedicle valve somewhat gibbous, often arching regularly from beak to front and depressed or concave between the umbo and the cardinal extremities which are somewhat prolonged. Beak a little elevated above the hinge line and incurved. Surface covered with striæ, those on the pedicle valve being often coarse, uneven and somewhat fasciculate; those on the brachial valve are more uniform, the stronger ones being distant and sharp with wide interspaces covered with very fine regular striæ.

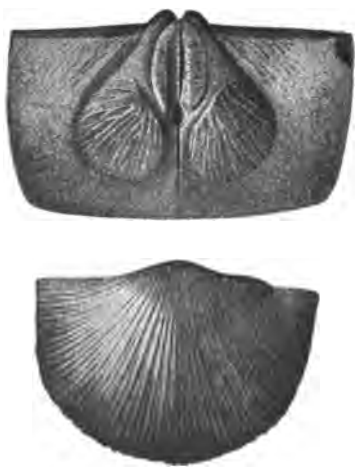

FIG. 259. *Stropheodonta inequiradiata*, with enlargement of interior of brachial valve.

Onondaga of New York, Ohio, Nevada, Quebec.

80. **S. hemispherica** Hall. (Fig. 260.) Devonic.

Form, size and general characters similar to *S. concava* from which it differs in having the surface striæ fine and nearly uniform, instead of alternating; generally also somewhat more convex than *S. concava*.

Schoharie and Onondaga of New York and equivalent horizons of Ohio, Indiana, Kentucky, and Ontario.

81. **S. concava** Hall. (Fig. 261.) Devonic.

Large with very convex pedicle valve. Cardinal areas high, almost at right angles to each other. Surface marked by strong sharp striæ with finer ones between, all crenulated by concentric striæ. Profile more concave than that of *S. demissa*.

Onondaga and Hamilton of New York.

82. **S. inæquistriata** (Conrad). (Fig. 262.) Devonic.

Small. Pedicle valve quite convex. Hinge line extended with acute and sometimes auriculate extremities. Surface marked by distant striæ with fine, almost invisible striæ between.

Onondaga–Hamilton of New York, Kentucky, Indiana, Wisconsin, Ontario.

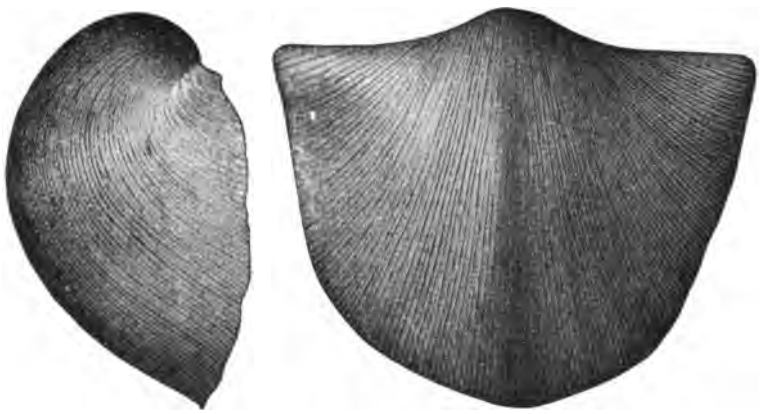

FIG. 260. *Stropheodonta hemispherica.*

83. **S. costata** Owen. Devonic.

Small (hardly 3/8 inch in diameter). Pedicle valve slightly convex; brachial valve nearly flat. Surface covered with about eleven prominent plications.

Hamilton of Iowa, Michigan.

84. **S. demissa** (Conrad). (Fig. 263.) Middle and Upper Devonic.

Length and width nearly equal. Pedicle valve strongly convex. Surface striæ numerous, strongest and most elevated near the beak and increasing by intercalation and bifurcation toward the front.

Widely distributed throughout North America, especially in Hamilton group.

85. **S. (Leptostrophia) perplana** (Conrad). (Fig. 264.) Devonic.

Thin, slightly convex, often almost flat. Extremities of hinge line usually prolonged. Surface covered with fine and nearly equal striæ, crenulated by fine concentric striæ. Differs from *S. corrugata* in its finer and less prominent striæ and in the absence of folds on the hinge margin.

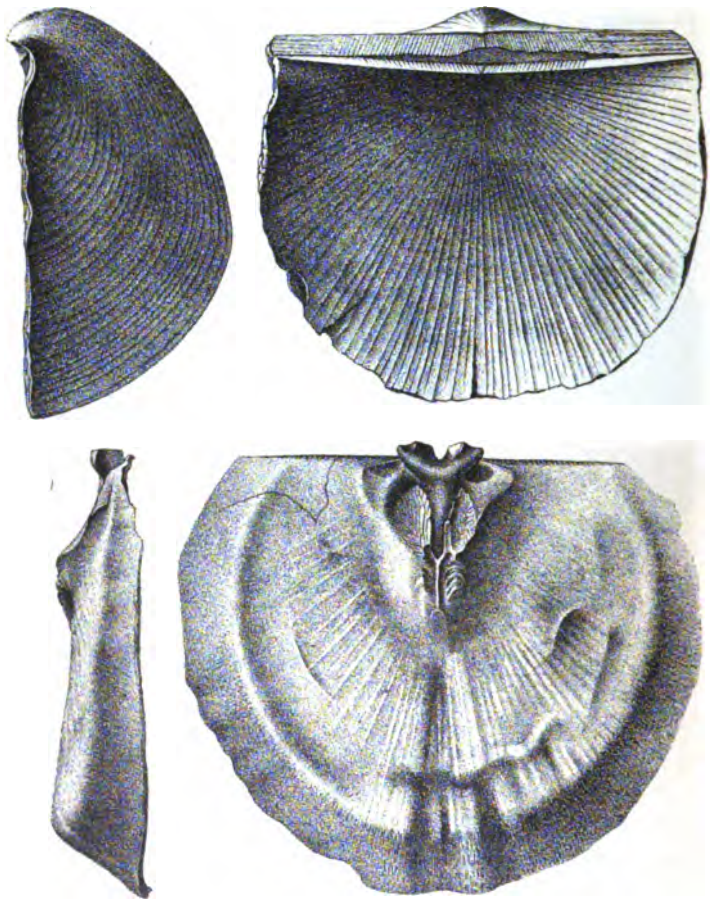

FIG. 261. *Stropheodonta concava*, lateral and dorsal view of exterior of complete shell; and lateral and front view of interior of brachial valve showing bilobed cardinal process, muscular scars; dental sockets, and crenulations of the hinge line, × 1. (After Hall.)

Onondaga – Chemung. Widely distributed throughout North America.

86. **S. arcuata** Hall. Devonic.

Hinge line scarcely equalling greatest width of shell below. Pedicle valve very arcuate with sometimes an undefined elevation along the center; cardinal extremities usually a little recurved, delthyrium

FIG. 262. *Stropheodonta inæquistriata*, pedicle valve, × 1. (After Hall.)

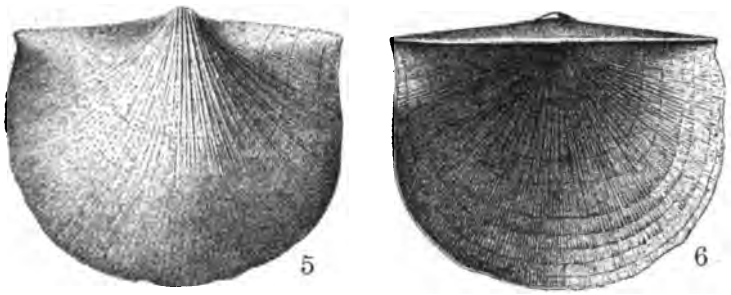

FIG. 263. *Stropheodonta demissa*, ventral and dorsal views, × 1. (After Hall.)

FIG. 264. *Stropheodonta* (*Leptostrophia*) *perplana*, ventral view, and interior of brachial valve.

closed. Brachial valve very concave. Surface covered with strong, sharply elevated radiating striæ each alternating with three or five smaller ones.

Chemung of New York, Iowa, Nevada, Manitoba.

XXXIII. PHOLIDOSTROPHIA Hall and Clarke.

Differs from *Stropheodonta* in the smooth, often nacreous surface; marked only with a few squamose growth lines. The interior of the brachial valve bears three diverging ridges in front of the muscle area. Devonic.

FIG. 265. *Pholidostrophia iowaensis*, dorsal, profile and ventral views, × 1. (After Hall.)

87. **P. iowaensis** (Owen). (Fig. 265.) *S. nacrea* Hall. Devonic.

Small, semielliptical, having a brilliantly nacreous lustre. Brachial valve concave; pedicle valve convex. Beak small and depressed. Surface apparently smooth, but crossed by microscopic growth lines.

Onondaga and Hamilton of New York, Ohio, Michigan, Indiana, Illinois, Kentucky, Iowa, Ontario.

XXXIV. STROPHONELLA Hall.

Pedicle valve concave; brachial convex. Otherwise like *Strophe-odonta*. Siluric–Devonic.

88. **S. patenta** (Hall). (Fig. 266.) Siluric.

Average shell 1⅜ inches long by 1⅝ inches wide; very convex. Surface covered with fine inequal radiating striæ crossed by

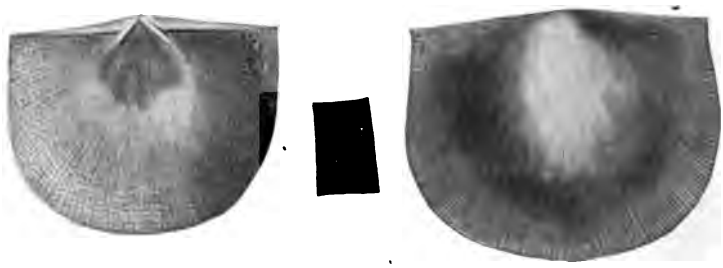

FIG. 266. *Strophonella* (?) *patenta*, with enlargement of surface features. (After Hall.)

fine concentric ones. Inner surface of valves thickly covered with sharp points.

Clinton of New York, Ohio, Indiana, Alabama.

89. **S. striata** Hall. (Fig. 267.) Siluric.

Almost flat with fine radiating striæ which increase by implantation. Average shell ⅝ inch long and ¾ inch wide.

Niagara of New York, Kentucky, Indiana.

FIG. 267. *Strophonella striata*. (After Hall.)

90. **S. headleyana** Hall. (Fig. 268.) Devonic.

Length about three fourths the width. Pedicle valve concave, especially near the front and with scarcely elevated beak. Brachial valve depressed at umbo and very convex toward the front. Cardinal area quite wide and marked by transverse striæ. Radiating striæ coarse and sharply elevated, increasing chiefly by implantation.

Helderbergian of New York, Kennedy Channel and Cape Frazier of the Arctic regions.

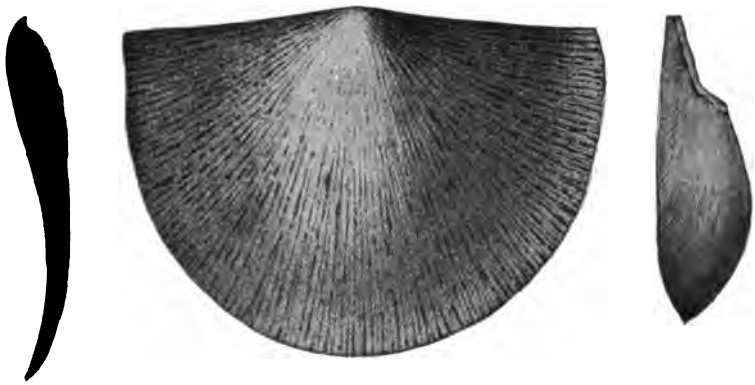

FIG. 268. . *Strophonella headleyana*, profile and ventral view (exterior); interior profile of pedicle valve. (After Hall.)

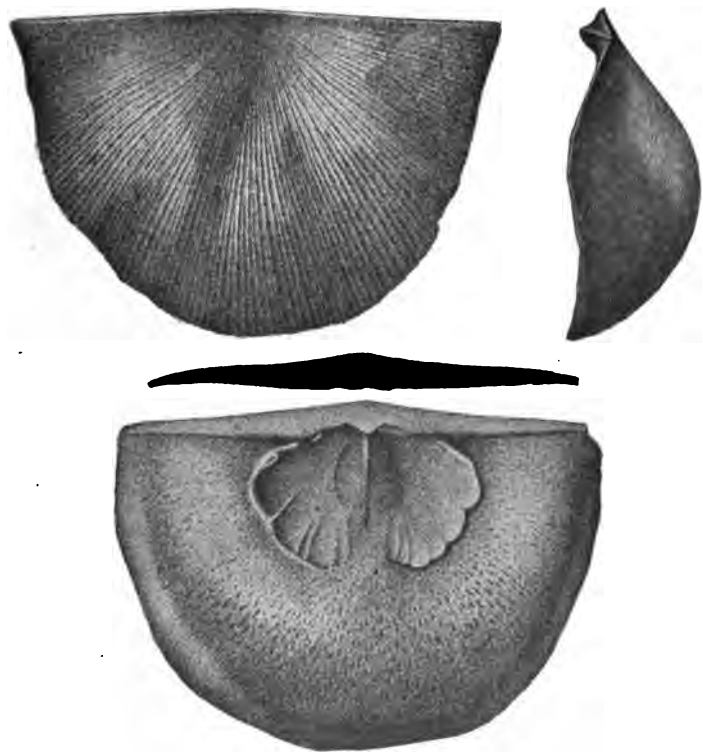

FIG. 269. *Strophonella ampla*, dorsal and profile views of brachial valve; cardinal view and interior of pedicle valve. (After Hall.)

91. **S. leavenworthana** Hall. Devonic.

Distinguished by its strong geniculation toward the front and by its concentric wrinkles, presenting a partial superficial resemblance to *Leptæna rhomboidalis.*

Helderbergian of New York.

92. **S. punctulifera** (Conrad). Devonic.

About four fifths as long as wide. Cardinal area narrow. Striæ strong, increasing both by bifurcation and intercalation and distinctly punctate. The shell outline is much more abruptly curved than that of *S. headleyana.*

Helderbergian of Maine, New York, Pennsylvania, Tennessee, Nevada, Quebec, New Brunswick, Cape Hilgard and Louis Napoleon of the Arctic regions.

93. **S. ampla** Hall. (Fig. 269.) Devonic.

Large, length from two thirds to three fourths as great as width. Pedicle valve very concave. Brachial valve convex in the middle and flat or concave at the umbo. Surface covered with angular, subequal, interrupted or rugose striæ which bifurcate two or three times before reaching the margin. In this species resupination is more marked, and the muscle impressions are stronger than in *S. headleyana.*

Onondaga of New York, Ohio, Ontario.

94. **S. reversa** Hall. (Fig. 270.) Devonic.

Semi-circular to semi-elliptical, with hinge line extended; about one third of the shell (young) normal, after which it becomes strongly and abruptly reversed. Striæ simple, strong and angular near beaks, dichotomizing from one to three times towards front; also increasing by implantation. Entire surface punctate.

FIG. 270. *Strophonella reversa*, dorsal and ventral aspects. (After Hall.)

In the Chemung of New York and equivalent beds of Iowa.

XXXV. STROPHOMENA (Rafinesque) Blainville.

Like *Rafinesquina* but with the convexity of the valves reversed. Pedicle valve slightly convex at umbo, becoming concave towards the middle; cardinal area conspicuous with convex deltidium; mus-

cular area subcircular and deeply excavated with an elevated ridge nearly surrounding it. Brachial valve slightly concave at umbo, rapidly becoming convex. Ordovicic–Carbonic.

A. Shell nearly flat..... 95. *S. billingsi.*
B. Shell strongly concavo-convex, *i. e.*, pedicle valve concave and brachial convex.. *.
* Shell triangular in outline. Cardinal extremities marked by oblique wrinkles. 98. *S. trilobata.*
* Shell transversely extended with acute hinge extremities..... (1).
(1) Large, over 1½ inch wide..... 96. *S. incurvata.*
(1) Small, less than 1½ inch wide..... 97. *S. trentonensis.*
* Shell subquadrate with more or less rectangular hinge extremities..... (2)
(2) Of medium size, about 1⅓ inches wide..... 99. *S. neglecta.*
(2) Small, less than 1⅓ inches wide..... *a.*
a. Shell not wrinkled on cardinal margin..... 100. *S. rugosa.*
a. Shell obliquely wrinkled on cardinal margin. 100*a*. *S. rugosa subtenta.*

95. **S. billingsi** Winchell and Schuchert. Ordovicic.

Small, usually not exceeding one inch in width. Both valves nearly flat; beaks scarcely distinct from the cardinal area. Brachial valve marked by a very faint mesial depression for about half the way from the beak to the front of the shell. Radiating striæ fine and usually of different sizes.

Trenton of Minnesota, Ontario, Manitoba.

96. **S. incurvata** (Shepard). (Fig. 271, *a–d.*) Ordovicic.

Of medium size, usually about one and three fourths inches wide, with greatest width along the hinge-line and with cardinal extremities acutely angular and deflected. Pedicle valve strongly concave; brachial quite strongly convex. Radiating striæ fine, crowded, alternating in size and crossed by numerous concentric lines and a few stronger growth lines.

Trenton of New York, Kentucky, Tennessee, Missouri, Iowa, Wisconsin, Minnesota, Manitoba.

97. **S. trentonensis** Winchell and Schuchert. (Fig. 272, *a.*) Ordovicic.

Valves thin. Radiating striæ delicate. Cardinal margins marked by oblique wrinkles. Internal markings undefined.

Trenton of New York, Kentucky, Tennessee, Wisconsin, Minnesota.

98. **S. trilobata** (Owen). (Fig. 271, *g–h.*) Ordovicic.

Hinge line extended. Brachial valve broadly trilobate and very gibbous in front. Radiating striæ fine and equal.

Trenton of Iowa, Minnesota, Manitoba.

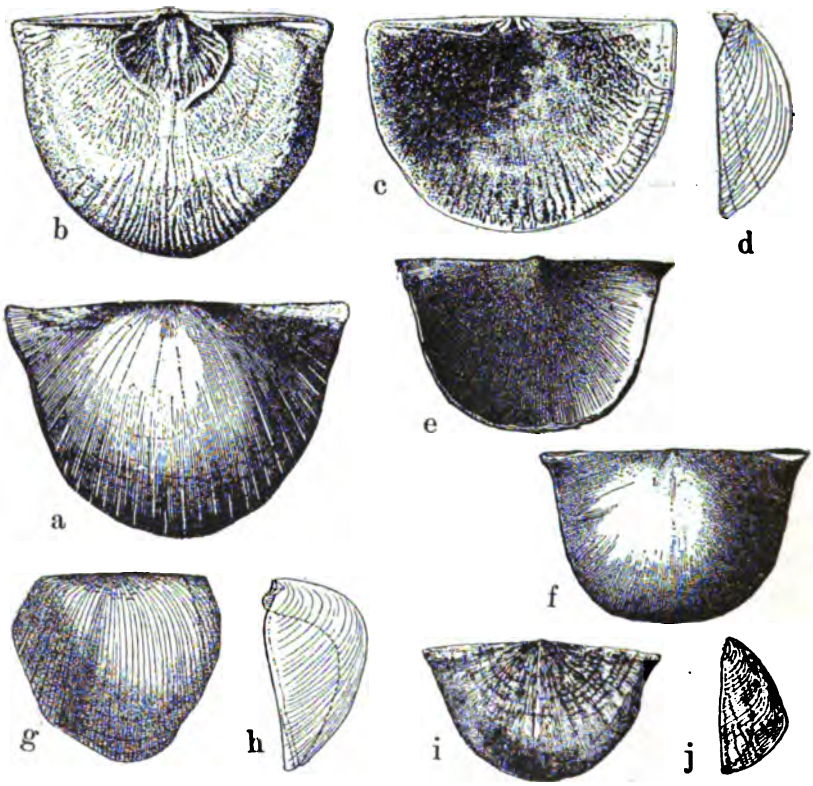

FIG. 271. *a–d, Strophomena incurvata, a,* exterior of convex brachial valve; *b,* nterior of pedicle valve, *c,* interior of brachial valve; *e–f, Strophomena rugosa,* ventral and dorsal views; *g–h, Strophomena trilobata,* dorsal and profile views; *i–j, Leptæna unicostata,* exterior and profile views of ventral valve. All natural size. (*e–f* after Indiana Geol. Surv., the others after Winchell and Schuchert, Minn. Geol. Surv.)

99. **S. neglecta** (James). (Fig. 272, *b.*) Ordovicic.

Of medium size, about one and one third inches wide by an inch in length with usually the greatest width at the hinge line. Sides meet the hinge line about at a right angle. Surface covered with fine, subequal radiating striæ.

Lorraine of Ohio, Indiana, Illinois, New Mexico.

100. **S. rugosa** (Rafinesque MS.) Blainville. (Fig. 271, *e–f.*) Ordovicic.

Pedicle valve deeply concave, brachial evenly convex. Of medium size with greatest width at the hinge line. Cardinal extremities somewhat acute. Surface covered with numerous fine

and close radiating striæ, usually several smaller between two larger, the smaller being always shorter than the larger.

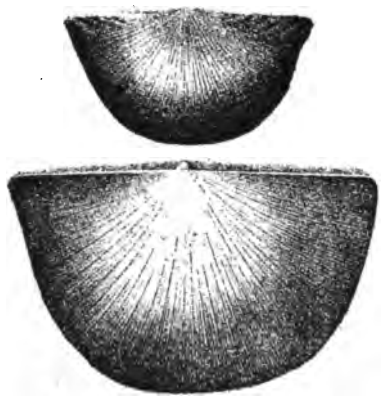

FIG. 272. *a* (upper), *Strophomena trentonensis; b, Strophomena neglecta*, dorsal views. (After Hall.)

Lorraine of Ohio, Indiana, Kentucky, Missouri, Wisconsin, Minnesota, Manitoba, Anticosti.

100, *a.* **S. rugosa** var. **subtenta** (Hall). Ordovicic.

Differs from *S. rugosa* in being obliquely wrinkled along the cardinal margins.

Occurs with the preceding in the Lorraine of Ohio, Indiana, Kentucky, Missouri, Minnesota and Anticosti.

XXXVI. LEPTÆNA Dalman.

Very similar to *Rafinesquina*, but wider in proportion to its length and usually with the flatter portions of the valves marked

FIG. 273, *a. Leptæna rhomboidalis* (Niagaran type.)

with conspicuous concentric wrinkles; where these cease the shell

is often abruptly and rectangularly deflected. The whole exterior is marked with fine radial striations. Ordovicic–Carbonic.

101. **L. rhomboidalis** (Wilckens). (Fig. 273, *a*–273, *b*.)
Ordovicic–Lower Carbonic.

Small, usually semicircular; cardinal extremities often much extended. Pedicle valve slightly convex near the hinge, slightly concave just before the deflection.

Trenton–Waverly; generally distributed throughout America and Europe.

FIG. 273, *b*. *Leptæna rhomboidalis*, interior of brachial valve, profile and dorsal view. Helderbergian type. (After Hall & Clarke.)

102. **L. unicostata** Meek and Worthen. (Fig. 271, *i*–*j*.)
Ordovicic.

Distinguished from the preceding by the complete absence of concentric wrinkles and the presence of a small mesial ridge on the outside of the pedicle valve.

Lorraine of Illinois, Wisconsin, Minnesota, Iowa, Manitoba.

XXXVII. PLECTAMBONITES Pander.

Small. Pedicle valve convex, brachial concave. Hinge line forming greatest width of shell. Cardinal areas narrow. Cardinal process large and simple, almost filling the delthyrium. Dental plates continued around the long, narrow, muscular areas. Surface striæ very fine, often alternating in size. Ordovicic–Siluric.

103. **P. sericeus** (Sowerby). (Fig. 274, *a–b.*) Ordovicic–Siluric.
Pedicle valve convex in center, deflected at edge. Striæ fine,

FIG. 274, *a*. *Plectambonites sericeus*, pedicle valves showing variation. (After Hall.)

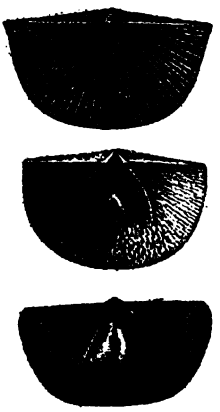

FIG. 274, *b*. *Plectambonites sericeus*, exterior dorsal aspect, and interior of pedicel and brachial valves, × 2. (After Hall.)

alternating with a few slightly elevated ones and crossed by a few weak concentric ones. Surface shining.

Trenton–Clinton of New York, Ohio, Kentucky, Indiana, Missouri, Wisconsin, Minnesota, Manitoba.

104. **P. transversalis** (Wahlenberg). (Fig. 275.) Siluric.
Pedicle valve very convex, brachial very concave. Hinge line, owing to the strongly incurved beak of the pedicle valve, is inflected.

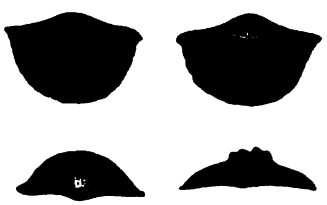

FIG. 275. *Plectambonites transversalis*, ventral, dorsal and profile views and cardinal view of interior of brachial valve. (After Hall.)

Surface marked by distant and strongly elevated striæ with exceedingly fine ones between. The strongly incurved beak of this species is very different from the small beak of *P. sericeus* which is scarcely distinct from the cardinal margin.

Clinton–Niagara of New York, Indiana, Wisconsin, Ontario, New Brunswick, Anticosti.

XXXVIII. SCHUCHERTELLA Girty.

(*Orthothetes* of authors.)

Shell flat. Much like *Strophomena*. Pedicle valve with well-developed cardinal area, often irregular. Brachial valve with narrow cardinal area. Cardinal process bilobed when viewed from within, quadrilobed when viewed from without, a faint median

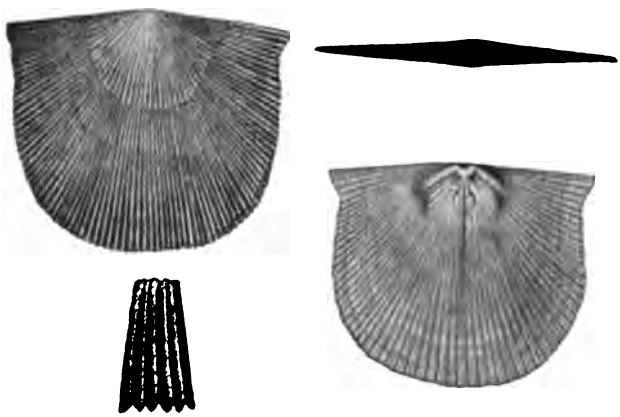

FIG. 276. *Schuchertella subplanus*. (After Hall.)

septum present. Surface covered with slender radiating striæ crenulated by sharp concentric growth lines or fine plications. Sil.-Carb.

105. **S. subplanus** (Conrad). (Fig. 276.) Siluric and Devonic.

Length and width nearly equal. Hinge line extended. Pedicle valve at first convex, later becoming concave. Striæ coarse, sharp and angular.

Niagaran and Helderbergian of New York, Kentucky, Tennessee, Indiana, Illinois, Missouri, Ontario, Nova Scotia, Anticosti.

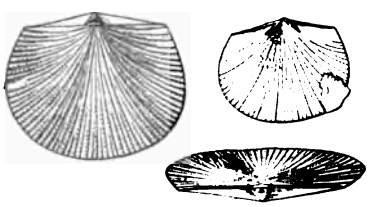

FIG. 277. *Schuchertella interstriatus*.

106. **S. interstriatus** (Hall). (Fig. 277.) Siluric.

Semioval, subplano-convex. Pedicle valve much elevated at the beak. Radiating striæ strong, not arcuate, with interstitial striæ beginning below the beak. Interior of shell marked with dichotomous, radiating striæ. All radiating striæ crossed by rather strong growth lines.

Cobleskill of New York, Greenfield of Ohio, etc.

107. **S. woolworthanus** (Hall). (Fig. 278.) Devonic.

Semielliptical. Both valves depressed convex at beak, concave toward the front. Beaks small. Surface with small, round, crowded,

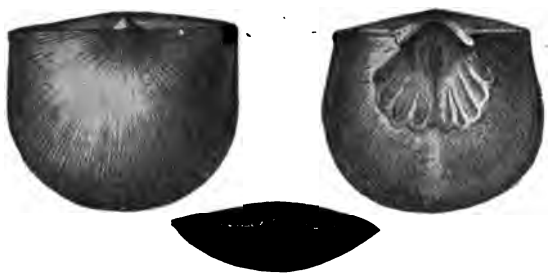

FIG. 278. *Schuchertella woolworthanus.* (After Hall.)

radiating striæ, increasing by interstitial addition, crossed by fine growth striæ and few larger lines of growth. Interior of pedicle valve marked by a large, flabellate muscular area.

Helderbergian of New York.

108. **S. pandora** (Billings). (Fig. 279.) Devonic.

Differs from *S. chemungensis* in the more regularly bilateral position of the umbo and in its lesser prominence; also in the less rectangular form of the shell.

Schoharie and Onondaga of New York, Ohio, Ontario, Nevada.

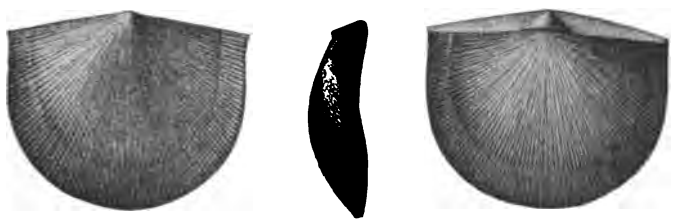

FIG. 279. *Schuchertella pandora.*

109. **S. arctostriatus** Hall. (Fig. 280, *a–b.*) Devonic.

Semielliptical or semicircular, often unsymmetrical. Pedicle valve slightly convex at umbo, flattened anteriorly; beak often distorted; cardinal area usually unequal on the two sides of the foramen. Brachial valve usually depressed convex. Surface covered with sharp, close, crenulated, radiating striæ, increasing mainly by

interstitial addition. Length about ¼ to ¾ inch, width slightly greater.

Hamilton of New York, Ohio, Kentucky and Nevada.

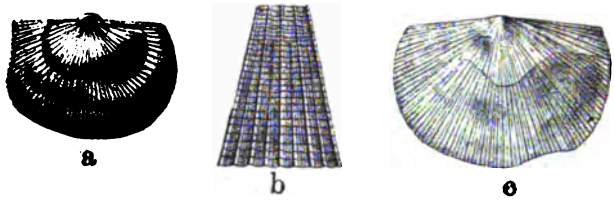

FIG. 280. *a*, *Schuchertella arctostriatus*; *b*, enlargement of surface; *c*, *Schuchertella perversus*. (After Hall.)

110. **S. perversus** (Hall). (Fig. 280, *c*.) Devonic.

Subelliptical. Hinge line less than the greatest width of shell. Length and width about as two to three. Front broadly rounded. Pedicle valve very convex at umbo and less so toward the front; beak distorted; deltidium prominent and convex. Brachial valve most convex above the middle, depressed toward the front. Surface marked with distant, elevated striæ, increasing by interstitial additions; interspaces crossed by elevated, undulating striæ.

Onondaga and Hamilton of New York, Nevada and Ontario.

111. **S. chemungensis** (Conrad). (Fig. 281, *a–b*.) Devonic.

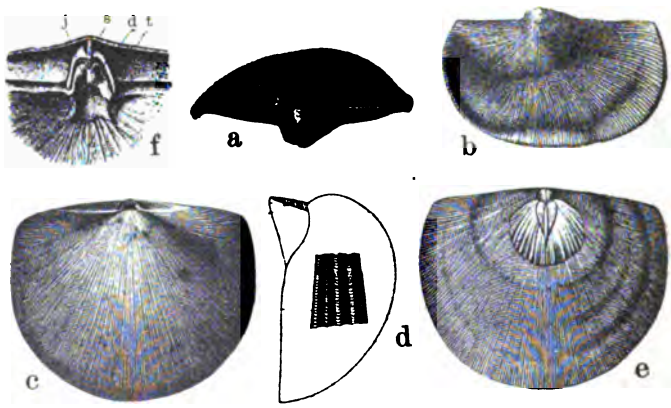

FIG. 281. *a*, *b*, *Schuchertella chemungensis* (× ⅔); *c–e*, *S. crenistria* (× ⅔); *Orthotetes keokuk* (× ⅔). (After Hall.)

Pedicle valve slightly concave, with prominent umbo. Angles of the hinge line with the sides nearly rectangular.

Chemung of New York, Pennsylvania, Ohio, Nevada, Manitoba.

112. S. inæqualis Hall. Mississippian.

Hinge line equalling the greatest width of the shell. Brachial valve very gibbous, with the greatest convexity near the center Pedicle valve nearly flat. Surface marked by alternating larger and smaller radiating striæ.

Kinderhook of Pennsylvania, Ohio, Iowa, Utah.

113. S. crenistria (Phillips?). (Fig. 281, *c–e.*) Mississippian.

Wider than long, with hinge line slightly shorter than width of the shell below. Brachial valve convex medially, pedicle valve flattened. Surface covered with numerous subequal or alternating larger and smaller radiating striæ, crossed by fine and crowded concentric striæ. Length of a rather large specimen 1¾ inches and breadth 2 inches.

Ohio, Michigan, Nevada, Nova Scotia, Feilden Isthmus in lat. 82°. 43′.

XXXIX. Orthotetes Fischer de Waldheim.

(*Derbya* of authors generally.)

In general like *Schuchertella* but the pedicle valve is at times much elevated at the beak and is rarely concave. It differs distinctly from *Schuchertella* in the presence in the pedicle valve of a high median septum extending longitudinally through the center of the muscular area, which is one third to two thirds the length of the valve. Carbonic.

114. O. (Derbya) keokuk Hall. (Fig. 281, *f.*) Mississippian.

Differs from *O. crassa* in its broadly semielliptical outline and convexity of brachial valve which is often equal to one third the width of the shell.

Kinderhook-Keokuk of Iowa, Illinois, Indiana, Missouri, Nevada.

115. O. (Derbya) crassus (Meek and Hayden). (Fig. 282, *a–d.*) Upper Carbonic.

Subquadrate, owing to the broadly rounded front and somewhat straightened lateral margins. Pedicle valve nearly flat and usually with a somewhat distorted beak. Brachial valve gently convex in the middle. Surface marked by numerous raised radiating striæ crossed by concentric lines and stronger growth lamellæ. Average size about 1 inch in length and breadth.

Widely distributed through central and western North America.

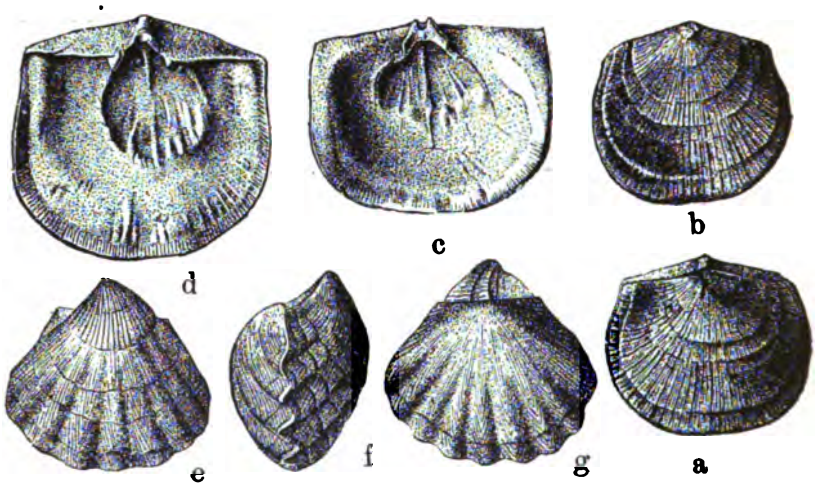

FIG. 282. *a–d, Orthotetes crassus; e–g, Meekella striatocostata.* (Ind. Geol. Surv.)

XL. MEEKELLA White and St. John.

Very biconvex; often subpyramidal; surface plicated. Hinge line straight, shorter than the greatest width of the shell. Cardinal area of pedicle valve high, with deltidium which is convex in the middle and flat along the sides. The prominent dental lamellæ are prolonged forward as septa for half the length of the shell. Cardinal area of brachial valve linear; umbo gibbous; cardinal process thin, erect and high, at times almost reaching the apex of the umbonal cavity of the pedicle valve. Surface of valves, including the coarse radiating plications, covered with fine radiating striæ. Upper Carbonic.

116. **M. striatocostata** (Cox). (Fig. 282, *e–g.*) Upper Carbonic.

Beak usually distorted by being flattened. Surface of both valves marked by 10 to 14 angular plications, not extending to the beak and separated by deep angular interspaces. The whole surface covered with fine radiating striæ which in maturity converge upon the crests of the plications and meet one another.

Distributed throughout the western United States.

XLI. HIPPARIONYX Vanuxem.

Large, like *Schuchertella* but with a very convex brachial valve which has no cardinal area; cardinal process high and bifid. Pedicle valve nearly flat, with low cardinal area. Teeth supported

by lamellæ which extend as strong ridges entirely around the large muscular area. Oriskany (Devonic).

117. **H. proximus** Vanuxem. (Fig. 283.) Devonic.

Pedicle valve nearly flat; its interior marked by strong muscular imprints which occupy a large cardiform space. The imprint of

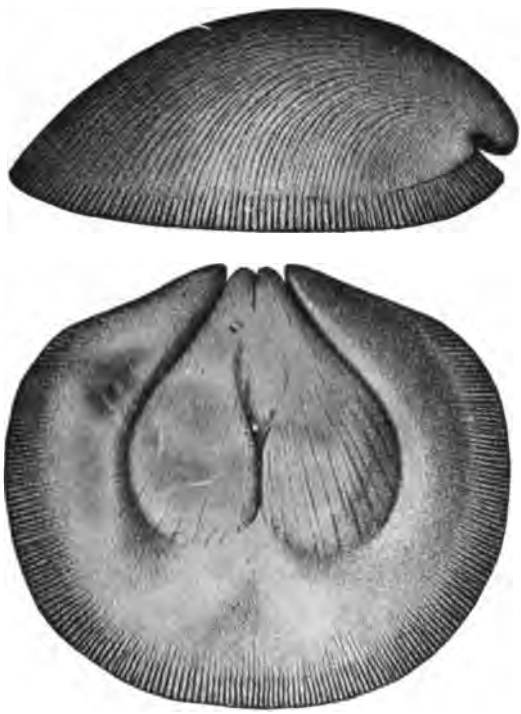

FIG. 283. *Hipparionyx proximus.* (After Hall.)

this on the internal mold suggested the name of "horse's hoof." Brachial valve convex; surface marked by fine subequal striæ.

Oriskany of New York, Pennsylvania, Ontario, etc.

XLII. CHONETES Fischer de Waldheim.

Small. Pedicle valve convex; brachial concave or flat. Hinge line straight, forming greatest diameter of shell. Hinge areas narrow, that of the pedicle valve bearing a single row of hollow spines on its upper margin. Muscular area of both valves divided by a low median ridge. Cardinal process simple. Surface covered with radiating striæ. Siluric–Carbonic.

A. Shell with radiating striæ ..... I.
I. Pedicle valve with a mesial sinus ..... *.
* Sinus very deep, giving the shell a bilobed appearance.
134. *C. verneuilianus.*
* Sinus with a mesial fold in it ..... 132. *C. mesolobus.*
* Sinus shallow and without mesial fold ..... *a.*
a. Shell about three fourths inch wide ..... 131. *C. granulifer.*
a. Shell smaller than above ..... 1.
1. Hinge line forming greatest width of shell... 133. *C. variolatus.*
1. Hinge line equal to or greater than greatest width of shell below ..... 126. *C. lepidus.*
I. Pedicle valve without a mesial sinus ..... **.
** Five to seven oblique spines on each side of the beak ..... *b.*
b. Shell large (about 1 inch wide) ..... 2.
2. Lateral striæ curved anteriorly ..... 118. *C. jerseyensis*
2. Lateral striæ straight ..... 122. *C. coronatus*
b. Shell small (about ½ inch wide) ..... 3.
3. Shell with 100–120 striæ near front ..... 129. *C. illinoisensis.*
3. Shell with 50–60 striæ near front ..... 124. *C. scitulus.*
** Two to four spines on each side of the beak (except 118 which may have more) ..... *c.*
c. Spines vertical ..... 125. *C. setigerus.*
c. Spines oblique ..... 4.
4. Shell large (three fourths inch wide or more) ..... †
† Striæ curving ..... 118. *C. jerseyensis.*
† Striæ not curving ..... 119. *C. hemisphericus.*
4. Shell of medium size (½ ± inch in general) ..... ††.
†† Hinge line forming the greatest width of the shell ..... *aa.*
aa. Umbo of pedicle valve very abruptly incurved at the hinge line ..... 123. *C. pusillus.*
aa. Umbo of pedicle valve not abruptly incurved.
128. *C. logani.*
†† Hinge line less than the greatest width of the shell below ..... *bb.*
bb. Striæ uniform ..... 121. *C. vicinus.*
bb. Two central striæ stronger than the others.
126. *C. lepidus.*
4. Shell small (about one fourth inch wide) ..... †††.
††† Spines bending abruptly until parallel to the hinge line.
120. *C. mucronatus.*
††† Spines not bending abruptly ..... 127. *C. aurora.*
B Shell smooth ..... 130. *C. glaber.*

118. **C. jerseyensis** Weller. (Fig. 284.) Siluric.

FIG. 284. *Chonetes jerseyensis.* (After Weller.)

Concavo- to plano-convex. Pedicle valve depressed convex. Cardinal spines slightly oblique, about 14. Surface of both valves with rather coarse radiating ribs, 3 or 4 in a space of 2 mm. at the anterior margin; the lateral ribs often curve slightly anteriorly as they approach the margin. Very fine concentric lines also present. Large shell measures 14 mm. in length by 22 mm. in width.

Decker Ferry of New Jersey, Cobleskill, etc., of New York.

119. **C. hemisphericus** Hall. (Fig. 285, *a–b.*) Devonic.

Hinge line often much extended and with 3, 4 or more spines on

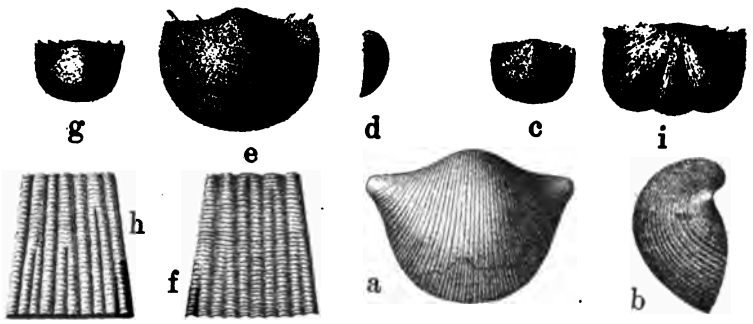

FIG. 285. *a, b, Chonetes hemisphericus, c, d, C. pusillus; e, f, C. aurora,* with enlargement of surface; *g, h, C. logani,* with enlargement of surface; *i, C. mesolobus.* (After Hall.)

each side of the middle. Pedicle valve very ventricose with prominent, incurved umbo. Shell about ¾ inch or 1 inch wide.

Onondaga of New York, Nevada, Ontario.

120. **C. mucronatus** Hall. (Fig. 286.) Devonic.

Small (about ¼ inch in width), moderately convex with rather distant and strong radial striæ. Cardinal spines, 2–3 on each

FIG. 286. *Chonetes mucronatus,* ×2. (After Hall.)

side of the beak, curving out so abruptly as to become parallel to the hinge line.

Oriskany–Hamilton of New York, Nevada, Ontario, Quebec.

121. **C. vicinus** (Castelnau). (Fig. 287.) Devonic.
Shell ½ ± inch in width, strongly convex. Cardinal margins deflected when seen from the convex side. Striæ finer and more closely crowded than in *C. mucronatus*. Spines short and oblique.

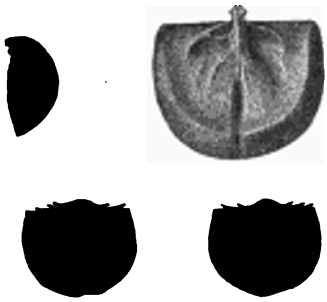

FIG. 287. *Chonetes vicinus*, with enlargement of interior of brachial valve. (After Hall.)

Hamilton of New York, Ohio, Wisconsin, Nevada.

122. **C. coronatus** (Conrad). (Fig. 288.) Devonic.
Large (about ½ inch in width), moderately convex, with numerous surface striæ and 5 or 6 oblique spines on each side of the beak. Interior of pedicle valve strongly pustulose outside the wide spreading adductor impressions.

Hamilton of New York, Pennsylvania, Illinois, Wisconsin, Ontario.

123. **C. pusillus** Hall. (Fig. 285, *c–d*.) Devonic.
Small (about ½ inch wide) with somewhat convex pedicle valve;

FIG. 288. *Chonetes coronatus*. (After Hall.)

its umbo abruptly incurved at the hinge extremities which are usually obtuse. Brachial valve nearly as concave as the pedicle is convex. Striæ but little elevated.

Hamilton of Illinois, British America.

124. **C. scitulus** Hall. (Fig. 289, *a–b.*) Devonic.

Somewhat gibbous, with numerous (50–60) striæ near the front of the shell and many (10–14) oblique cardinal spines. Interior of brachial valve strongly pustulose.

Marcellus–Chemung of New York, Pennsylvania, Ohio.

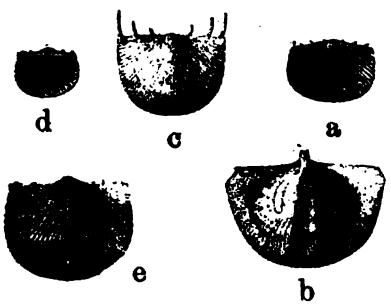

FIG. 289. *a*, *Chonetes scitulus*; *b*, same, interior of brachial valve, × 2; *d*, *e*, *C. Lepidus*, natural size and enlarged; *c*, *C. setigerus*, ×2. (After Hall.)

125. **C. setigerus** (Hall). (Fig. 289, *c.*) Devonic–Lower Carbonic.

Moderately convex with three vertical cardinal spines on each side of the beak.

Marcellus–Waverly of New York, Pennsylvania, Ohio, Michigan, Nevada.

126. **C. lepidus** Hall. (Fig. 289, *d–e.*) Devonic.

Similar to *C. scitulus* but is smaller, the pedicle valve is more convex, with a mesial sinus and 4 to 10 marginal spines.

Marcellus–Chemung of New York and Pennsylvania.

127. **C. aurora** Hall. (Fig. 285, *e–f.*) Devonic–Mississippian.

Differs from *C. logani* in its smaller size (about ¼ inch wide) and shorter hinge line, the hinge line being usually less than the greatest width of the shell.

Tully–Burlington of New York, Ohio, Iowa, Northwest Territory.

128. **C. logani** Norwood and Pratten. (Fig. 285, *g–h.*) Mississippian.

Pedicle valve quite convex. Greatest width of shell at hinge line (about ½ inch). Surface marked by 20–40 fine, dichotomizing, radiating lines, crossed by fine concentric striæ.

Kinderhook–Burlington of Ohio, Illinois, Iowa.

129. **C. illinoisensis** Worthen. Mississippian.

Small (about ½ inch wide), with five or six oblique spines on each side of the beak. Surface marked by 100–120 very fine dichotomizing striæ near the front of the shell.

Burlington of Ohio, Indiana, Illinois, Iowa.

130. **C. glaber** Geinitz. Upper Carbonic.

Slightly larger than *C. mucronatus*, thin, transversely subsemi-

circular. Length less than one-half breadth. Hinge line slightly longer than greatest width of shell below. Pedicle valve with a broad and shallow mesial sinus which is at times wanting. Cardinal margin with four to seven oblique spines on each side of the beak. Surface smooth except for faint concentric striæ.

Kansas, Iowa, Illinois, Colorado, Nebraska.

131. **C. granulifer** Owen. Upper Carbonic.

Rather large (about ¾ inch wide). Distinguished by the broad shallow sinus in the pedicle valve, the often extended hinge line and the presence of six to ten oblique spines on each side of the beak. Surface marked by very fine radiating striæ.

Alabama, Missouri, Illinois, Iowa, Kansas, Colorado, Arizona.

132. **C. mesolobus** Norwood and Pratten. (Fig. 285, *i.*) Upper Carbonic.

Small. Distinguished by the presence of a lobe or fold in the mesial sinus of the pedicle valve.

Ohio, Missouri, Illinois, Colorado, New Mexico, Arizona.

133. **C. variolatus** (d'Orbigny). Upper Carbonic.

Similar to *C. granulifer* but more convex, very small and with the sinus of the pedicle valve well-marked.

Ohio, Illinois, Missouri, Kansas, Nebraska, Colorado.

134. **C. verneuilianus** Norwood and Pratten. (Fig. 290.) Upper Carbonic.

Small and much wider than long with extended and sometimes mucronate hinge extremities. Pedicle valve bearing a deep, rounded mesial sinus, giving the valve a two-lobed appearance. Hinge line with four oblique spines on each side of the beak. Brachial valve bearing an obtuse median fold. Surface marked by many fine radial striæ. Especially distinguished from other species by its deep sinus and bilobed appearance.

Indiana, Illinois, Missouri, Kansas, Nebraska, Colorado.

FIG. 290. *Chonetes verneuilianus*, two pedicle valves showing variation. (Ind. Geol. Surv.)

XLIII. CHONOSTROPHIA Hall and Clarke.

Differs from *Chonetes* in having the pedicle valve concave and the brachial convex; in the absence of a median septum in the brachial valve and in the bilobed cardinal process.

135. **C. complanata** Hall. (Fig. 291, *a.*) Devonic.

Width 1 inch or more. About two thirds as long as wide. Cardinal spines directed obliquely outwards. Surface with fine, closely arranged, bifurcating striæ.

Oriskany of New York, Ontario and Cumberland, Md.

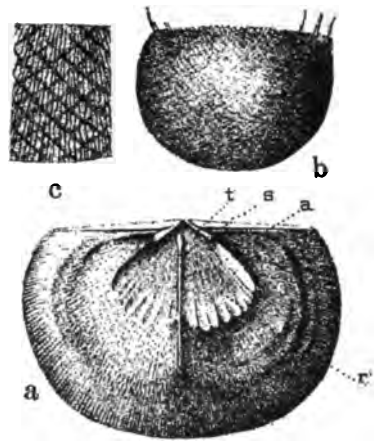

FIG. 291. *a, Chonostrophia complanata; b, Chonopectus fischeri; c,* enlargement of surface of same. (After Hall.)

XLIV. CHONOPECTUS Hall and Clarke.

Chonetes-like in shape and presence of spines but with the beak of the pedicle valve depressed or distorted, leaving a flattened area which is probably a scar from attachment in early growth. Surface ornamented with a normal series of concentric growth lines and also with a double oblique series of wrinkles looking much like the "engraving on a machine-turned watch case."

Kinderhook and Burlington (Lower Carbonic).

136. **C. fischeri** (Norwood and Pratten.) (Fig. 291, *b, c.*) Lower Carbonic.

Semielliptical. Hinge line with five to seven nearly straight spines on each side of the beak. Surface marked by fine radiating and concentric striæ, beneath which is a "textile" appearance due to a double set of diagonal lines.

Kinderhook and Burlington, of Pennsylvania, Iowa, Missouri, etc.

XLV. STROPHALOSIA King.

Small, semicircular. Hinge line straight. Beak of pedicle valve with scar indicating attachment. Cardinal area of pedicle valve especially conspicuous; delthyrium large, covered; teeth large and cardinal process erect and bifid. Surface of pedicle valve covered with spines; that of brachial valve spinous, lamellose or smooth. Devonic–Carbonic.

137. **S. truncata** (Hall). (Fig. 292.) Devonic.

Small. Pedicle valve gibbous, regularly arched and truncated at the umbo. Cardinal extremities flattened and auriculate. Brachial valve gently concave. Surface of both valves covered with scattered spines.

Hamilton, Portage and Ithaca of New York, Nevada, Ontario.

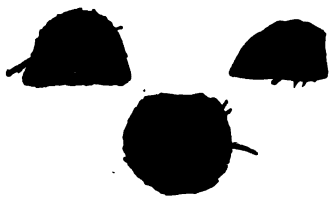

FIG. 292. *Strophalosia truncata.* (After Hall.)

XLVI. PRODUCTELLA Hall.

Productoid. Small, with straight hinge line and narrow cardinal areas. Pedicle valve strongly convex and produced anteriorly, with overarching beak; deltidium present; teeth small. Brachial valve small, concave; cardinal process usually bilobed. Surface marked by radiating ridges which bear spines at intervals. Differs from Strophalosia also in the lack of umbonal attachment. Devonic–Carbonic.

A. Spines numerous ..... *.
  * Length much greater than breadth ..... 138. *P. navicella.*
  * Length and breadth about equal ..... 1.
    1. Spines arranged in concentric rows ..... 142. *P. speciosa.*
    1. Spines irregularly scattered ..... *a.*
      a. Brachial valve moderately concave ..... 1′.
        1′. Lamellose growth lines present ..... 144. *P. pyxidata.*
        1′. Lamellose growth lines not present ..... 145. *P. shumardana.*
      a. Brachial valve very concave ..... 2′.
        2′. Cardinal margins conspicuously flattened ... 139. *P. spinulicosta*
        2′. Cardinal margins not conspicuously flattened. 146. *P. concentrica.*

B. Spines few and scattered ..... **.
  ** Length much greater than breadth, radiating striæ coarse. 143. *P. arcuata.*
  ** Length and breadth about equal, radiating striæ fine ..... 141. *P. hallana.*
  ** Length much less than breadth. ..... 140. *P. subalata.*

138. **P. navicella** Hall. (Fig. 293, *a–b.*) Devonic.

Small; length much exceeding width. Hinge line less than

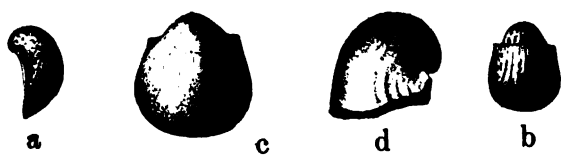

FIG. 293. *a, b, Productella navicella; c, d, P. spinulicosta.* (After Hall.)

width of shell below. Pedicle valve projecting about one third its length above the hinge line. Surface marked above by fine spines and below by coarse, spine-bearing ridges.

Onondaga–Hamilton of New York, Nevada.

139. **P. spinulicosta** Hall. (Fig. 293, *c–d.*) Devonic.

Differs from *P. navicella* in the broadly semielliptical or suborbicular outline and in the beak of the pedicle valve which does not extend beyond the hinge line as in *P. navicella.*

Widely distributed in the Onondaga and Hamilton of North America.

140. **P. subalata** Hall. (Fig. 294, *a.*) Middle Devonic.

Semielliptical or semicircular, usually much wider than high Distinguished by the irregularly scattered spines on the surface.

Illinois, Missouri, Minnesota.

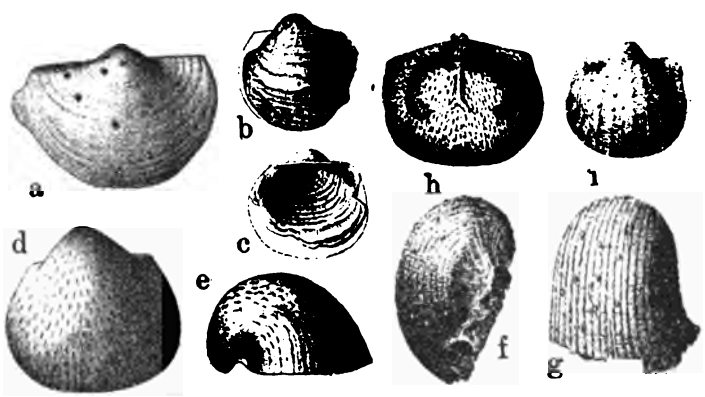

FIG. 294. *a, Productella subalata; b, c, P. hallana; d, e, P. speciosa; f, g, P. arcuata; h, P. pyxidata; i, P. shumardana.* (After Hall, except *b, c,* which are after Walcott.)

141. **P. hallana** Walcott. (Fig. 294, *b–c.*) Upper Devonic.

Semielliptical. Length and breadth nearly equal. Pedicle valve very convex with umbo elevated above the hinge line. Brachial valve deeply concave. Surface of pedicle valve marked by fine radiating striæ, a few strong growth lines and a few scattered spines. Surface of brachial valve marked only by regular concentric lines.

New York, Iowa, Nevada, Northwest Territory.

142. **P. speciosa** Hall. (Fig. 294, *d–e.*)
Devonic–Lower Carbonic.

Broadly ovate with obtusely angular cardinal extremities Pedicle valve regularly arcuate from beak to front and abruptly depressed between the umbo and the narrow, short ears. Surface marked by fine concentric striæ and on the ears by a few short wrinkles. The whole body of the shell covered with about 25 concentric rows of spine-bearing tubercles.

Portage, Chemung and Kinderhook of New York, Ohio, Iowa, Nevada.

143. **P. arcuata** Hall. (Fig. 294, *f, g.*) Lower Carbonic.

Length exceeding width. Pedicle valve very gibbous with greatly incurved beak. Differs from *P. navicella* in its larger size and in the almost entire absence of spines on the radial costæ.

Kinderhook of Iowa, Ohio and Missouri.

144. **P. pyxidata** Hall. (Fig. 294, *h.*)
Lower Carbonic.

Width greater than length. Hinge line shorter than greatest width of shell. Pedicle valve somewhat flattened and slightly recurved at the cardinal extremities; umbo narrow. Surface of both valves marked with lamellose growth lines; spine-bearing radiating ridges at times present on pedicle valve.

Kinderhook of Illinois and Missouri.

145. **P. shumardana** Hall. (Fig. 294, *i.*) Lower Carbonic.

Hinge line about equalling the greatest width of shell. Pedicle valve very convex, gibbous in the middle and towards the umbo; cardinal extremities flattened. Brachial valve moderately concave. Surface of both valves covered with fine concentric striæ and strong spine bases. Differs from *P. pyxidata* in the absence of lamellose growth lines.

Kinderhook of Missouri, Iowa and Ohio.

146. **P. concentrica** Hall. Lower Carbonic.

Small. Hinge line scarcely equalling the greatest width of shell. Brachial valve deeply concave, almost geniculate in front. Surface of older portion of valve covered with strong concentric wrinkles and a few tubercles; the younger portion with elongate spine-bearing ridges.

Kinderhook of Ohio, Indiana, Iowa and Michigan.

XLVII. Productus Sowerby.

Semicircular without functional pedicle but probably anchored by spines of pedicle valve. Pedicle valve large, convex, with inflated and greatly incurved umbo. Brachial valve small, concave or almost flat. Hinge line straight; cardinal areas and teeth absent or rudimentary. Cardinal process, large, four-lobed when viewed from within. A median ridge in each valve separates the muscular areas. Surface with radiating ribs crossed by concentric lines or wrinkles, the surface of pedicle valve often studded with spines. Carbonic.

A. Large (over two inches wide) ..... *.
* Surface marked with regular concentric folds from beak to front.
160. *P. punctatus.*
* Surface marked with very coarse striæ and a few concentric wrinkles.
152. *P. semireticulatus.*
B. Medium (between one and two inches wide) ..... **.
** Sinus present ..... 1.
1. Beak greatly incurved ..... 148. *P. burlingtonensis.*
1. Beak small, slightly incurved ..... *a*.
a. Radiating striæ coarse ..... 154. *P. costatus.*
a. Radiating striæ very fine ..... 155. *P. inflatus.*
** Sinus absent ..... 2.
2. Hinge line somewhat shorter than width of shell below ..... *b*.
b. Spines few and scattering ..... 153. *P. cora.*
b. Spines very numerous ..... 1′.
1′. Spines in 2 series; one series of large the other of small spines.
159. *P. nebraskaensis.*
1′. Spines in a single series ..... 161. *P. symmetricus.*
2. Hinge line much shorter than width of shell below (equalling only about half the width) ..... 147. *P. lævicosta.*
C. Small (less than one inch wide) ..... ***.
*** Hinge line equal to or exceeding the width of the shell below ..... 3.
3. Sides flattened, giving the shell a four-sided appearance from the hinge-margin. No sinus ..... 157. *P. mexicoanus.*
3. Not four-sided ..... *c*.
c. Hinge line extended. Broad mesial sinus ..... 156. *P. longispina.*
c. Hinge line not extended ..... 158. *P. muricatus.*
*** Hinge line less than width of shell below ..... 4.
4. Surface marked by concentric wrinkles ..... *d*.
d. With a marginal fold ..... 150. *P. marginicinctus.*
d. Without a marginal fold ..... 149. *P. biseriatus.*
4. Surface marked by radiating striæ ..... 151. *P. fasciculatus.*

147. **P. lævicosta** White. Lower Carbonic.

Subtriangular in general outline, rapidly increasing in width from the small, narrow beak to near the front where it is broadly

rounded. No mesial depression present. Hinge line short, forming scarcely more than half the width of the shell. Surface marked with very fine, thread-like striæ. Spine bases scarcely visible.

Kinderhook of Iowa, Missouri, Utah.

148. **P. burlingtonensis** Hall. (Fig. 295, *a–c.*) Lower Carbonic.

Pedicle valve extremely ventricose with beak incurved to near the middle of the valve; median sinus present, extending from near the beak to the front. Brachial valve moderately concave above and abruptly geniculate in the middle. Surface marked by

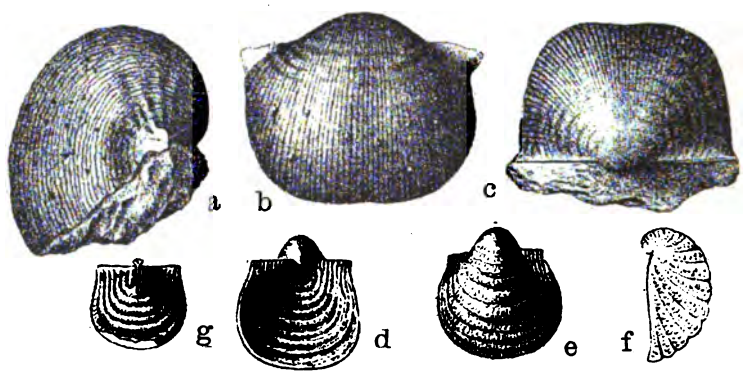

FIG. 295. *a–c, Productus burlingtonensis; d–g, P. biseriatus.* (After Hall and Whitfield.)

radiating bifurcating ribs crossed by fine concentric striæ. Strong wrinkles present on the upper portion of the shell and scattered spines on the middle and lower parts.

Burlington of Illinois, Iowa, Missouri, Utah.

149. **P. biseriatus** Hall. (Fig. 295, *d–g.*) Lower Carbonic.

Small, longitudinally ovate; hinge line scarcely as long as the width of the shell below. Pedicle valve extremely gibbous, without sinus and marked by five or six elevated, distant, concentric undulations which bear on their upper margins a row of elongate nodes and below this many smaller granulations. Beak attenuate and extremely arcuate. Brachial valve flat near the front and marked by 8 or 9 concentric bands set with granulations.

St. Louis of Kentucky, Indiana, Illinois, Missouri.

150. **P. marginicinctus** Prout. Lower Carbonic.

Brachial valve subquadrate. A conspicuous marginal fold or cincture present on each valve. Surface covered with prominent, rounded, bifurcating costæ, the point of bifurcation marked by a spine base. Fine concentric striæ cover the entire surface; these are accompanied on the older portion of the shell by prominent concentric wrinkles. Width about 1 inch; length somewhat less.

St. Louis of Illinois and Missouri.

151. **P. fasciculatus** McChesney. Lower Carbonic.

Hinge line shorter than width of the shell below. Beak small and appressed. Pedicle valve sharply arcuate above and gently curving, with a slight depression. Surface marked with moderately fine radiating striæ which, when well preserved, have an irregular knotty appearance caused by the thickening of the striæ

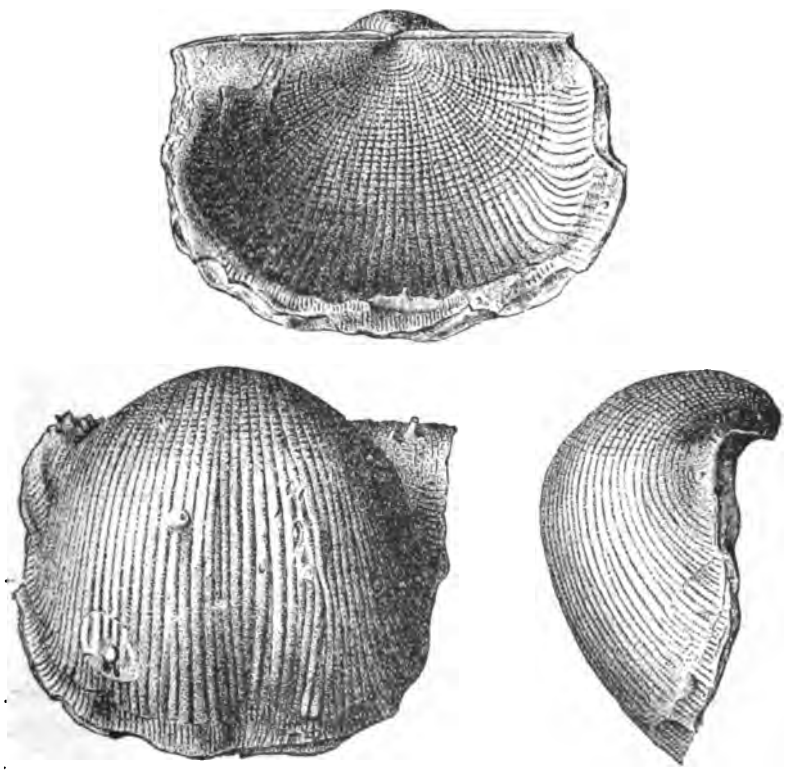

FIG. 296. *Productus semireticulatus.* (Ind. Geol. Surv.)

at the spine bases. Very fine concentric growth lines present in front and above a few obscure transverse wrinkles.

Kaskaskia of West Virginia, Kentucky, Ohio, Indiana, Missouri. Illinois, Utah.

152. **P. semireticulatus** (Martin). (Fig. 296.)
Lower and Upper Carbonic.

Large, much like *P. costatus* in form and character of plications, but larger and with less distinct plications which are crossed by regular concentric wrinkles in younger stages. Shallow mesial sinus present giving the shell a bilobed appearance.

Throughout the Carbonic of North America.

153. **P. cora** d'Orbigny. (Fig. 297, *a–b.*) Upper Carbonic.

Pedicle valve uniformly convex with beak scarcely projecting above the hinge line. Mesial fold and sinus absent. Surface marked with fine radiating striæ and with a few scattered spines.

Throughout the Upper Carbonic of North America.

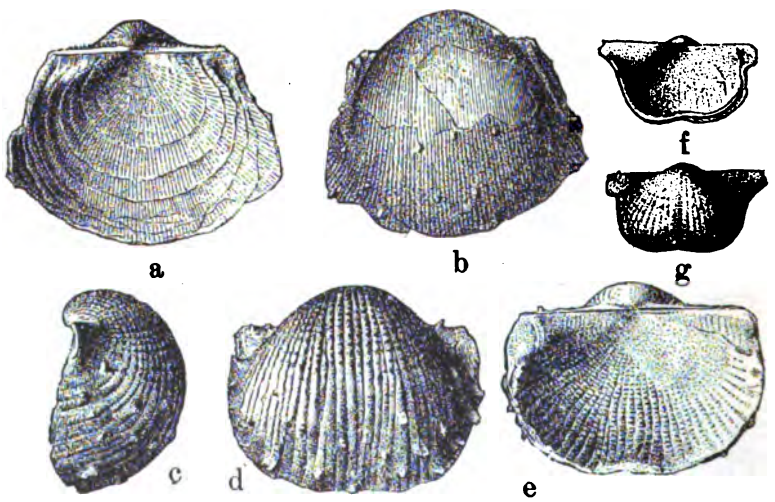

FIG. 297. *a, b, Productus cora; c–e, P. costatus; f–g, P. longispina.* (Ind. Geol. Surv.)

154. **P. costatus** (Sowerby?) de Koninck. (Fig. 297, *c–e.*)
Upper Carbonic.

Of medium size. Pedicle valve gibbous with a broad, shallow sinus producing a slight emargination at the anterior border. Beak prominent but only slightly projecting over the hinge mar-

gin. Brachial valve concave with a very slight mesial fold. Surface marked by coarse radiating plications sometimes bifurcating or coalescing and crossed by a few concentric wrinkles. A few strong, scattered spines present on the pedicle valve.

Throughout the Upper Carbonic of North America.

155. **P. inflatus** McChesney. Upper Carbonic.

Very gibbous, subquadrate in outline. Beak small and incurved. Sinus broad, shallow and distinct. Much resembles *P. semireticulatus* but differs in its smaller size and in the fineness of its radial striæ. Concentric wrinkles present in the posterior third. Spines few, distant and large.

Indiana and Colorado.

156. **P. longispina** Sowerby ? (Fig. 297, *f–g.*) Upper Carbonic.

Small, much wider than long with extended hinge line and prominent ears. Pedicle valve gibbous with slightly projecting beak and broad mesial sinus. Brachial valve concave. Surface marked by obscure radiating ribs which are obsolete on the umbo. Spines originally long but usually broken off.

Throughout the Upper Carbonic of the United States.

157. **P. mexicoanus** Shumard. Upper Carbonic.

Small. Sides flattened giving the shell a somewhat four-sided outline when viewed from the hinge margin. Pedicle valve strongly arched and without mesial sinus. Surface with 16–20 coarse radiating costæ on which are scattered spines.

Nevada, New Mexico.

158. **P. muricatus** Norwood and Pratten. Upper Carbonic.

Small, semicircular with breadth exceeding length. Curvature moderate. Distinguished by its surface markings, consisting of concentric nodose wrinkles and coarse, somewhat nodose striæ. Whole shell covered by small spines.

Ohio, Illinois, Missouri, Iowa, Colorado, New Mexico.

159. **P. nebraskaensis** Owen. (Fig. 298, *a–c.*) Upper Carbonic.

Of medium size. Distinguished by the absence of a distinct sinus in the pedicle valve and by the large number of spines scattered over the surface of both valves. (See *P. symmetricus.*)

Ohio, Indiana, Illinois, Missouri, Nebraska, Colorado, Nevada, New Mexico, Arizona.

160. **P. punctatus** (Martin). (Fig. 298, *d–e.*)

Upper Carbonic.

Distinguished by its large size, hinge line shorter than the width of the shell below, slight mesial sinus in the pedicle valve, small, incurved beak and numerous regular concentric folds with plain interspaces. Spines numerous, minute and appressed.

Widely distributed throughout North America.

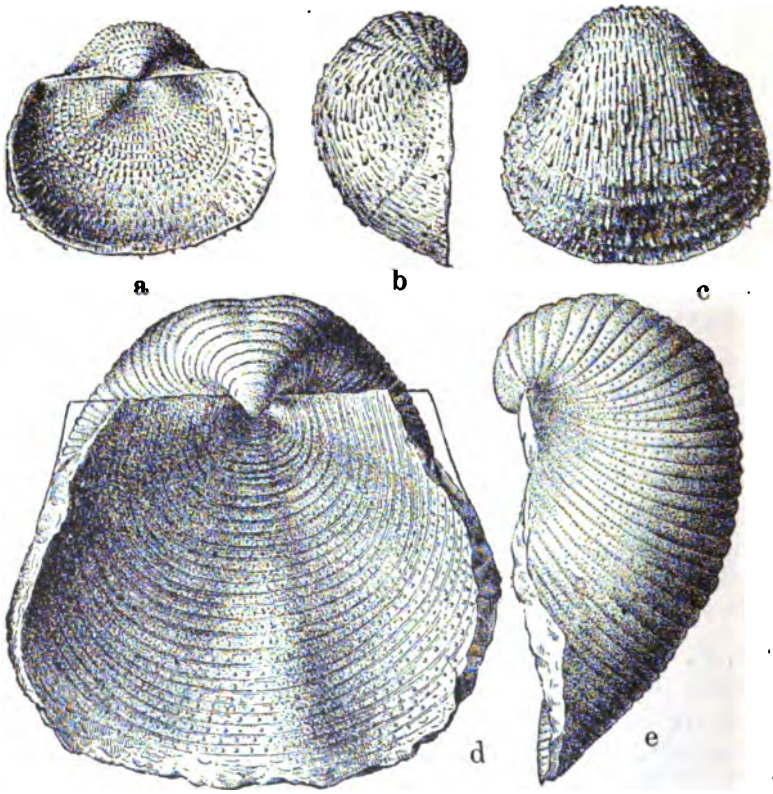

FIG. 298. *a–c, Productus nebraskaensis; d, e, P. punctatus* (Ind. Geol. Surv.)

161. **P. symmetricus** McChesney. (Fig. 299.)

Upper Carbonic.

Cardinal area a little less than greatest width of shell. Front broadly rounded. Pedicle valve without mesial sinus; ears obtusely angular, not well defined from the body of the shell. Brachial valve moderately concave. Surface covered with small concentric wrinkles, covered with many minute spines. Width

about two inches, length slightly less. Distinguished from *P. nebraskaensis* by its less convex pedicle valve its smaller concentric wrinkles, and especially by having a simple series of small rather compressed spines without the additional stout and erect series of spines.

Upper Carbonic of Indiana, Illinois, Iowa and Nebraska.

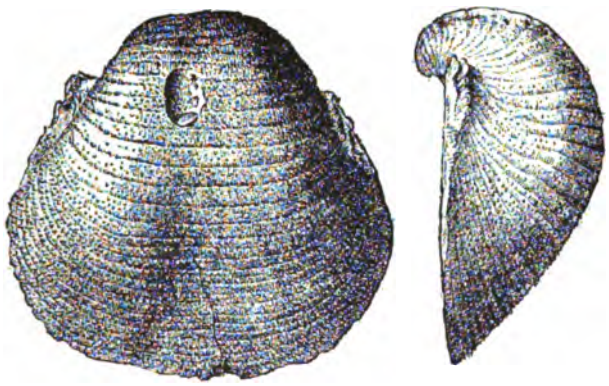

FIG. 299. *Productus symmetricus.* (Ind. Geol. Surv.)

ORTHIDÆ.

ORTHIS Dalman.

Under this name were formerly placed all forms having in general a straight hinge line, cardinal areas well developed in each valve with usually an open triangular delthyrium in each with deltidium developed only in younger growth stages. Dental lamellæ well developed in the pedicle valve and crural plates in the brachial valve. Surface covered with radiating striæ or plications.

This old genus of *Orthis* has been subdivided into *Orthis* (restricted), *Plectorthis*, *Dinorthis*, *Hebertella*, *Orthostrophia*, *Platystrophia*, *Heterorthis*, *Bilobites*, *Dalmanella*, *Rhipidomella*, *Schizophoria*, *Orthotichia*, *Enteletes*.

A. Shell radially plicate ..... *.

* Hinge line short (forming about one third the greatest width of shell. Shell globular ..... LVIII. *Enteletes.*

* Hinge line long ..... 1.

1. Pedicle valve flat or concave. Brachial convex ..... L. *Dinorthis.*

1. Pedicle valve convex ..... *a*.

a. Brachial valve flat ..... XLVIII. *Orthis.*

a. Brachial valve convex ..... 1′

1′. Strong mesial fold on brachial valve and corresponding sinus on pedicle valve ..... LIII. *Platystrophia.*

1′. No mesial fold present. Shallow sinus present or absent. XLIX. *Plectorthis.*

B. Shell surface radially striate (*i. e.*, radiating lines fine)..... **.

** Strongly two-lobed. Very small..... LIV. *Bilobites.*

** Not two-lobed..... 2.

2. Hinge line short (forming about one third the greatest width of shell).. *b.*

b. Valves subequally and gently biconvex..... LVI. *Rhipidomella.*

b. Brachial valve very convex; pedicle valve much less convex. LVII. *Schizophoria.*

2. Hinge line long..... *c.*

c. Shell substance punctate..... LV. *Dalmanella.*

c. Shell substance impunctate..... 2′.

2′. Muscular impression of pedicle valve small, almost confined between the dental lamellæ..... LII. *Orthostrophia.*

2′. Muscular impression of pedicle valve moderately large, extending about half the distance from the beak to the front of the shell..... LI. *Hebertella.*

XLVIII. Orthis Dalman (emend Hall and Clarke).

Brachial valve flat; pedicle valve convex. Cardinal area of pedicle valve elevated and somewhat incurved. Surface covered with strong, sharp and comparatively few plications which are usually if not always simple. Dental lamellæ slightly developed. Cardinal process, a vertical plate lying at the bottom of the brachial deltidial cavity, and longitudinally dividing it. Camb.–Carb.

162. **O. costalis** Hall. (Fig. 300, *a–b.*) Ordovicic.

Hinge line slightly less than the greatest width of the shell. Pedicle valve very convex with high cardinal area and beak not

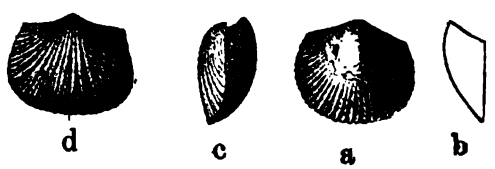

Fig. 300. *a, b, Orthis costalis; c, d, Plectorthis fissicosta.* (After Hall.)

incurved. Surface covered by about 30 distant, strong and rounded plications.

Chazy of New York.

163. **O. tricenaria** Conrad. (Fig. 301, *a–c.*) Ordovicic.

Distinguished from *O. flabellites* by its smaller size and strongly convex pedicle valve with very high cardinal area.

Trenton; widely distributed throughout North America.

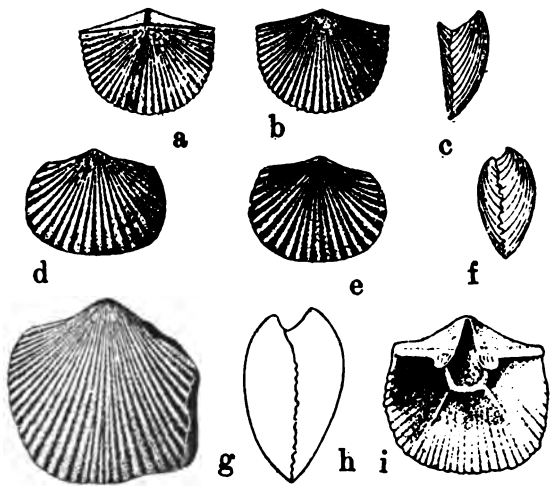

FIG. 302. *a–c, Orthis tricenaria; d–f, Plectorthis plicatella; g–i, P. whitfieldi.* (Min. Geol. Surv.)

164. **O. flabellites** Foerste. (Fig. 202.) Siluric.

Semioval, with long hinge line. The coarse plications crossed by concentric growth lines.

Clinton and Niagara of New York, Kentucky, Ohio, Indiana, Wisconsin, Ontario.

XLIX. PLECTORTHIS Hall and Clarke.

Differs from *Orthis* (restricted) in the subequal and convex valves, in having less simple plications and in the comparatively low cardinal area of the pedicle valve. Ordovicic – Devonic.

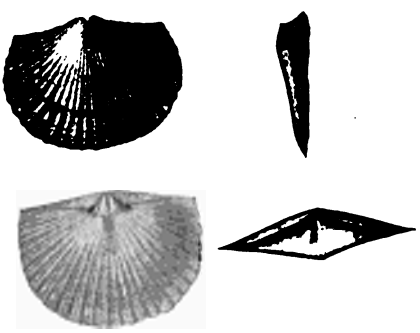

FIG. 202. *Orthis flabellites.*

165. **P. indianola** Walcott. Cambric.

Small, transverse. Hinge line varying from slightly less to one fifth greater than the width of the shell below. Pedicle valve about twice as convex as the brachial, with or without a mesial sinus. Brachialvalve with a shallow or deep mesial sinus. Cardinal areas low. Surface marked with strong or fine radiating ribs or striæ.

Middle and Upper Cambric of Indian Territory, Oklahoma, Texas.

166. **P. remnicha** Winchell. Cambric.

Of medium size, usually slightly transverse. Hinge line varying in length from nearly the greatest width of the shell to two thirds the greatest width. Cardinal areas narrow. Brachial valve slightly less convex than the pedicle. Surface marked by bifurcating radiating ribs that vary on shells of similar size from sixteen in the space of $\frac{1}{8}$ inch to 3 in the same space.

Saint Croix of Minnesota and Wisconsin, and equivalent formations of Wyoming, Montana, Indian Territory.

167. **P. plicatella** Hall. (Fig. 301, *d–f.*) Ordovicic.

Broadly semioval. Valves equally convex without depression or elevation. Length and breadth as 3 to 4. Cardinal area narrow. Plications about 20–28.

Trenton–Lorraine of New York, Kentucky, Ohio, Wisconsin, Minnesota.

168. **P. whitfieldi** (N. H. Winchell). (Fig. 301, *g–i.*) Ordovicic.

Larger than *P. plicatella* with an almost square outline. Cardinal area strongly elevated. Plications numerous.

Lorraine of Illinois, Iowa, Wisconsin, Minnesota.

169. **Plectorthis fissicosta** Hall. (Fig. 300, *c–d.*) Ordovicic.

Of medium size. Slightly and nearly evenly convex. Distinguished especially by the character of the costæ which are angular and become two or three times divided toward the margin of the shell.

Lorraine of Ohio.

L. Dinorthis Hall and Clarke.

Differs from *Orthis* (restricted) in the convex brachial valve, in the pedicle valve which is elevated at the umbo and becomes gradually depressed and finally flat or concave, in the dental lamellæ being extended around a subquadrate muscular area, and in having an erect cardinal process. Ordovicic.

170. **D. deflecta** (Conrad). (Fig. 303, *a–d.*) Ordovicic.

Brachial valve moderately convex. Hinge line usually forming the greatest diameter of the shell. Cardinal areas at right angles to each other with broadly triangular delthyrium partially covered

by a convex deltidium. Surface covered with many fine elevated striæ crossed by finer concentric lines.

Trenton of Kentucky, Tennessee, Illinois, Iowa, Wisconsin Minnesota.

171. **D. meedsi** Winchell and Schuchert. (Fig. 303, *e–h.*) Ordovicic.

Biconvex owing to the slight convexity of the pedicle valve. Hinge line shorter than the width of the shell below. Pedicle

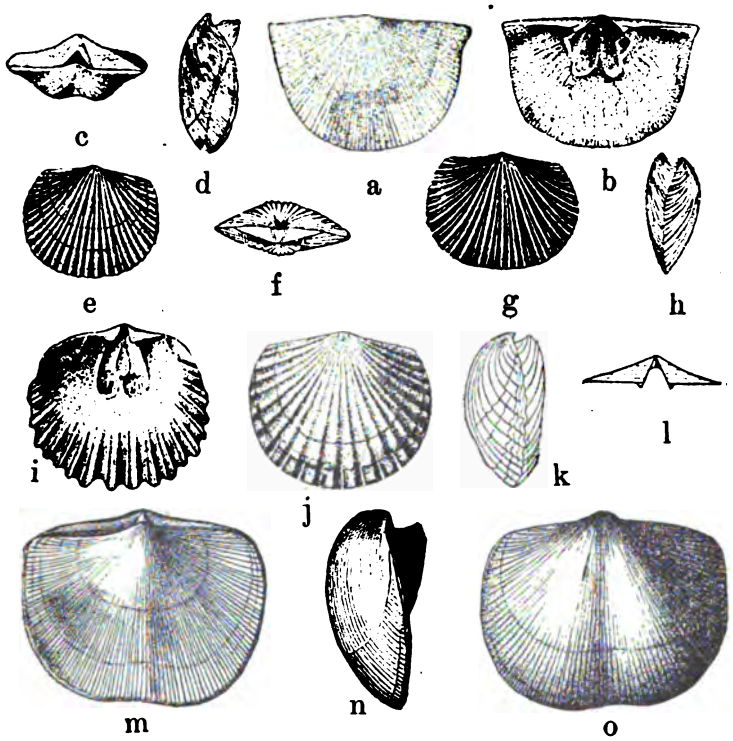

FIG. 303. *a–d, Dinorthis deflecta; e–h, D. meedsi; i–l, D. pectinella* (Min. Geol. Surv.); *m–o, D. subquadrata* (Ind. Geol. Surv.).

valve marked by a broad, shallow sinus. Surface marked by strong, sharp, fasciculated striæ crossed by growth lines.

Trenton of Iowa, Wisconsin, Minnesota.

172. **D. pectinella** (Emmons). (Fig. 303, *i–l.*) Ordovicic.

Pedicle valve flattened with a broad central depression. Brachial valve regularly convex. Surface marked with 22–30 prominent

radii which are as broad as the spaces between and present an appearance much like the radii of *Pecten*.

Trenton of New York, Pennsylvania, Iowa, Minnesota, Ontario, Manitoba.

173. **D. subquadrata** (Hall). (Fig. 303, *m–o*.) Ordovicic.

Larger and more subquadrate than the preceding species, the sides and front being nearly straight. Surface marked by sharp radiating striæ which increase by bifurcation and intercalation.

Lorraine of the Ohio Valley, Missouri, Illinois, Wisconsin, Minnesota, Iowa, Manitoba, Anticosti.

LI. Hebertella Hall and Clarke.

Cardinal area about equalling the greatest width of the shell, that of the pedicle valve being much the higher. Pedicle valve depressed, convex, always less convex than the brachial which is frequently much inflated. Both valves covered with fine, rounded and closely crowded striæ or plications which increase by intercalation; these are crossed by concentric growth lines. Dental lamellæ continued as a strong ridge around the obcordate muscular area. Cardinal process simple, elongate. Shell impunctate. Ordovicic–Siluric.

A. Small, less than ½ inch long ..... 175. *H. bellirugosa*.
B. More than ½ inch long ..... *.
* Broad sinus present on pedicle valve ..... 1.
1. Surface striate ..... *a*.
a. Striæ irregularly bifurcating. Beak moderately high. 177. *H. occidentalis*.
a. Striæ stronger and regularly bifurcating. Beak very high. 178. *H. sinuata*.
1. Surface plicate ..... 174. *H. borealis*.
* No sinus present on pedicle valve ..... 176. *H. insculpta*.

174. **H. borealis** (Billings). (Fig. 304, *a–c*.) Ordovicic.

Both valves convex. Hinge line somewhat less than the width of the shell below. Brachial valve with a low, undefined mesial prominence; pedicle valve with a broad and very shallow mesial sinus. Surface covered with about 40 radiating ribs. Much like *Plectorthis plicatella*, but differs in the presence of the fold and sinus.

Chazy–Trenton of Kentucky, Tennessee, Wisconsin, Minnesota. Ontario, Quebec.

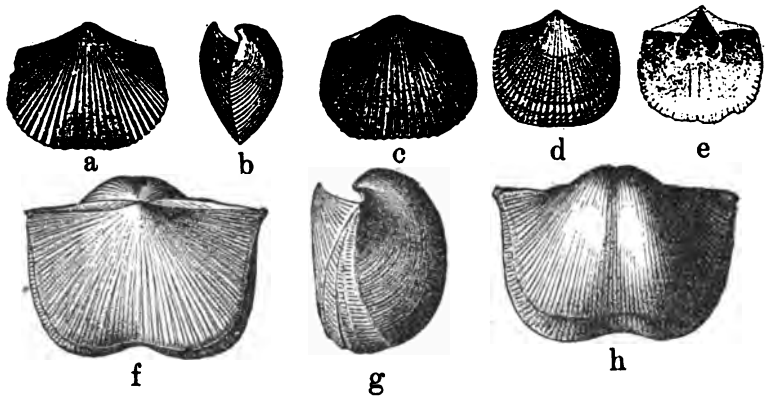

FIG. 304. *a–c*, *Hebertella borealis* (Geol. Surv. Canada); *d*, *e*, *H. bellirugosa* (Min. Geol. Surv.); *f–h*, *H. occidentalis* (Ind. Geol. Surv.).

175. **H. bellirugosa** (Conrad). (Fig. 304, *d–e*.) Ordovicic.

Small (less than ½ inch long), subquadrate. Valves of nearly equal convexity. Brachial valve with a conspicuous mesial sinus and pedicle valve also at times with a sinus. Surface striæ crossed by imbricating lamellæ which give the shell a rugose appearance.

Trenton of Kentucky, Tennessee, Wisconsin, Minnesota, Iowa.

176. **H. insculpta** Hall. (Fig. 305.) Ordovicic.

Distinguished from *H. bellirugosa* by its larger size (over ½ inch long), more convex brachial valve and less prominent concentric growth lines.

Lorraine of Ohio, Indiana, Illinois, Wisconsin, Iowa.

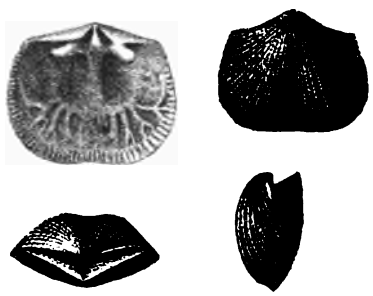

FIG. 305. *Hebertella insculpta*. (After Hall.)

177. **H. occidentalis** Hall. (Fig. 304, *f–h*.) Ordovicic.

Length and breadth about as 5 to 7. Cardinal area of pedicle valve high; delthyrium triangular, large and open. Pedicle valve high at beak, depressed into a broad sinus toward the front. Brachial valve regularly and strongly convex with greatly incurved beak which projects slightly beyond the hinge line. Surface marked by elevated, subangular striæ crossed by fine concentric growth lines.

Lorraine of Ohio, Indiana, Illinois, Missouri, Wisconsin, New Mexico.

178. **H. sinuata** Hall. (Fig. 306.) Ordovicic.

Very similar to *H. occidentalis* from which it differs in the more elevated and acute beak of the pedicle valve and in the stronger and more regularly bifurcating striæ.

Lorraine of Ohio.

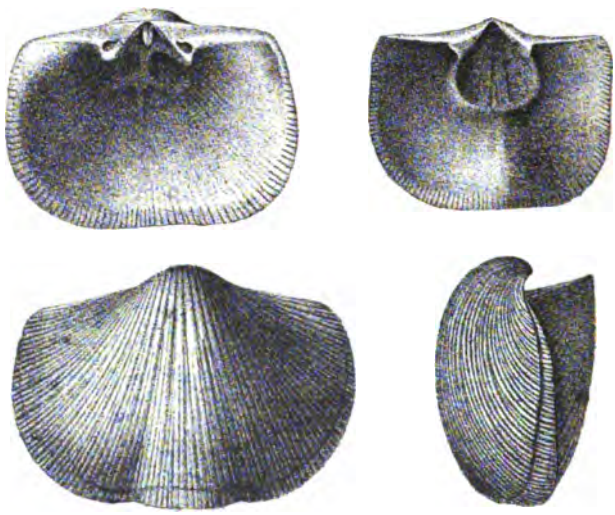

FIG. 306. *Hebertella sinuata.* (Ohio Surv.)

LII. ORTHOSTROPHIA Hall.

Pedicle valve depressed convex; brachial very convex. Surface striated. Cardinal process elongate and simple. Muscular area in pedicle valve deep and narrow, almost confined to the space between the dental lamellæ. The vascular markings are very distinct on both valves. Siluric–Devonic.

FIG. 307. *Orthostrophia (?) fasciata.* (After Hall.)

179. **O.(?) fasciata** Hall. (Fig. 307.) Siluric.

Distinguished by its small size, often extended hinge line and bifurcating and fasciculate striæ.

Niagara of New York.

180. **O. strophomenoides** Hall. Devonic.

Beak of pedicle valve but little elevated above the hinge line; that of brachial valve somewhat the more prominent. Surface marked by a distinct, narrow mesial elevation on the pedicle valve from beak to front and by a corresponding depression on the brachial valve.

Helderbergian of New York, Maine, Tennessee, etc.

LIII. PLATYSTROPHIA King.

Exterior spiriferoid but interior lacking the calcified brachidia of *Spirifer*. Hinge line long and straight. Cardinal areas almost equally developed on both valves, thus differing from *Spirifer*. Both valves very convex, the brachial the more so, with a strong median fold on the brachial valve and a corresponding deep sinus

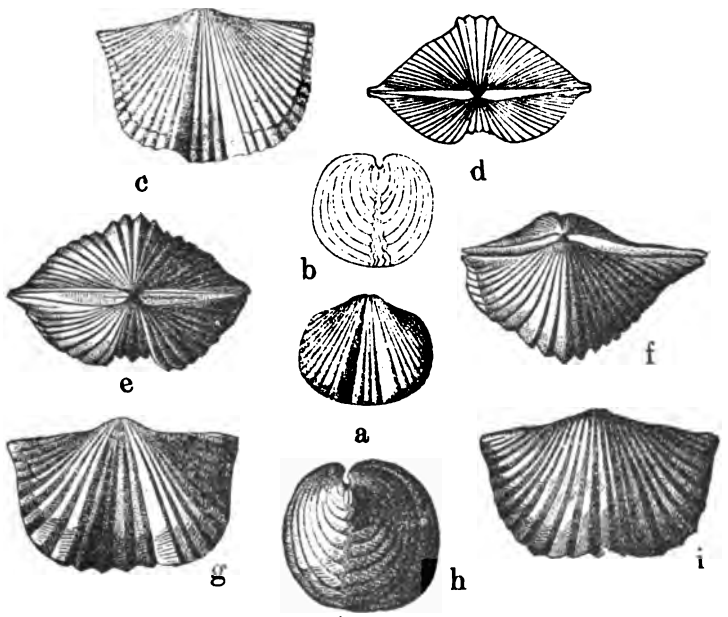

FIG. 308. *a, b, Platystrophia crassa; c, d, P. biforata* (Min. Geol. Surv.); *e–i, P. acutilirata* (Ind. Geol. Surv.).

on the pedicle valve. Both valves marked by strong sharp plications which extend over sinus and fold. The teeth are thick and very prominent. Ordovicic–Siluric.

A. Length and breadth about equal. Shell very gibbous..... 181. *P. crassa.*
B. Breadth exceeding length..... ..... *.
* Hinge line rounded at extremities and less than the greatest width of shell. 183. *P. lynx.*
* Hinge line extended 1
1. Five plications in sinus..... 185. *P. biforata.*
1. Three plications in sinus..... *a.*
a. Hinge line usually with mucronate extremities. Plications many. 1.
1. Fold pronounced..... .....185. *P. biforata.*
1. Fold not pronounced . ...182. *P. acutilirata.*
a. Hinge line extremities not mucronate. Plications wide and few. 184. *P. laticosta.*

181. **P. crassa** James. (Fig. 308, *a–b.*) Ordovicic.

Hinge line short with rounded extremities. Shell as wide as long. Both valves very gibbous.

Lorraine of Ohio, Minnesota, Manitoba.

182. **P. acutilirata** (Conrad). (Fig. 308, *e–i.*) Ordovicic.

Usually much extended on hinge line which is often mucronate Plications simple, from 10 to 18 on each side of fold and sinus with usually only three in the sinus and four on the fold.

Lorraine of Indiana, Ohio, Missouri and Louisiana.

183. **P. lynx** (Eichwald). (Fig. 309.) Ordovicic.

Large, wider than long. Hinge line usually less than the greatest width of the valves, with obtusely angular extremities. Plications (16–24) angular, with three to four in the mesial sinus.

Lorraine of Ohio, Kentucky, Indiana.

184. **P. laticosta** Meek. Ordovicic.

Of medium size, wider than long, with hinge line forming greatest width of shell. Plications large and few, 5 to 7 on the lateral slopes and usually three on the sinus and four on the fold; those marking fold and sinus are irregular and of different sizes.

Lorraine of Ohio.

185. **P. biforata** (Schlotheim). (Fig. 308, *c–d.*) Ordovicic and Siluric.

Semielliptical or subquadrate, wider than long. Cardinal extremities usually submucronate. Brachial valve the more convex. Usually about 3 (1–5) of the sharp plications are in the sinus while about 4 (2–7) mark the fold, rapidly increasing in strength as they approach the front.

Chazy–Niagara throughout North America.

LIV. Bilobites Linnæus.

Small, strongly bilobed. Hinge line short. Teeth and sockets obscure. Cardinal process small and simple. Shell substance punctate. Siluric–Carbonic.

186. **B. bilobus** (Linnæus). Siluric.

Cardinal extremities auriculate. Pedicle valve very convex; brachial valve varying from slightly concave to slightly convex.

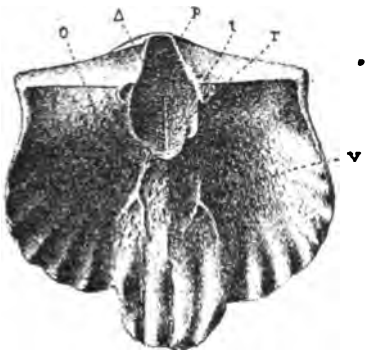

FIG. 309. *Platystrophia lynx*. Interior of pedicle valve × 1. Δ, delthyrium; *o*, ovarial impression; *p*, pedicle muscle scar; *r*, diductor muscle impression; *t*, teeth; *v*, vascular markings. (After Hall.)

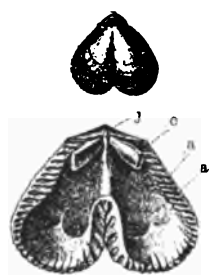

FIG. 310. *Bilobites varicus*. Exterior dorsal view × ⅔ and interior of brachial valve much enlarged; *j*, cardinal process; *c*, crura; *a*, adductor scars. (After Hall.)

Differs from *B. varicus* in its smaller size, its more extended hinge line, greater inequality of the two valves and in its few radial striæ.

Niagaran of New York, Indiana, Wisconsin.

187. **B. varicus** Conrad. (Fig. 310.) Devonic.

Ventricose. Cardinal area of pedicle valve the higher. Foramen high and narrow. Surface unequally striated, only a few of the striæ being visible to the naked eye. Differs from *B. bilobus* in its larger size, greater gibbosity. and proportionally shorter hinge line.

Lower Helderberg of New York, Tennessee, New Brunswick.

STÖBER'S METHOD OF MAKING CRYSTAL DRAWINGS.

By AUSTIN F. ROGERS.

In crystallographic work perhaps the thing that gives the most trouble is the making of the clinographic drawing ordinarily used in the description of crystals. The method of making the drawing is simple enough but the actual work is a tedious process for crystals that are at all complex.

There are a number of devices that shorten and simplify this work. Moses* describes a graphic method of obtaining the axial cross by using a diagonal scale and a quadrant giving sines and cosines particularly useful for monoclinic and triclinic crystals. Later † he describes a metal quadrant which makes the work still simpler. Story-Mackelyne's *crystallograph* ‡ is a metal instrument consisting of three graduated limbs cut to angles of the projected axes. This laid down on paper gives at once the axes for isometric crystals, which are modified for other systems. Penfield § has described an axial protractor, engraved axes of the isometric and hexagonal systems on drawing paper and three special triangles, which greatly facilitate the drawing of crystals.

In spite of these devices crystal drawing still remains a difficult task and while perhaps in the nature of the case it can never be simple it is believed that the following method described by Stöber || is perhaps the best one. As Stöber's article appeared in French it may not be amiss to describe his method in English so that it may have the extended notice it deserves.

The starting point is the stereographic projection. The plane of projection may be any oblique plane but for the sake of uniformity it is well to use the one given in most crystal drawings in which the angles of rotation to give the clinographic projection are 18°26′ and 9°28′.

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* SCHOOL OF MINES QUARTERLY, 15 : 214, 1894.

† *Amer. Jour. Sci.* (4), 1 : 462, 1896.

‡ "Morphology of Crystals," p. 481, 1895.

§ *Am. Jour. Sci.* (4), 19 : 39–75, 1905.

|| *Bull. soc. fr. Min.*, 22 : 42, 1899.

The stereographic projection of this plane is the arc *SMS'* (Fig. 1) in which the angle *BS* is 18°26′ and the angle *CM* is 9°28′ (stereographic degrees). As the arc of a circle with such a long radius requires a beam compass or curved ruler for its construction it is convenient to cut such an arc out of cardboard.

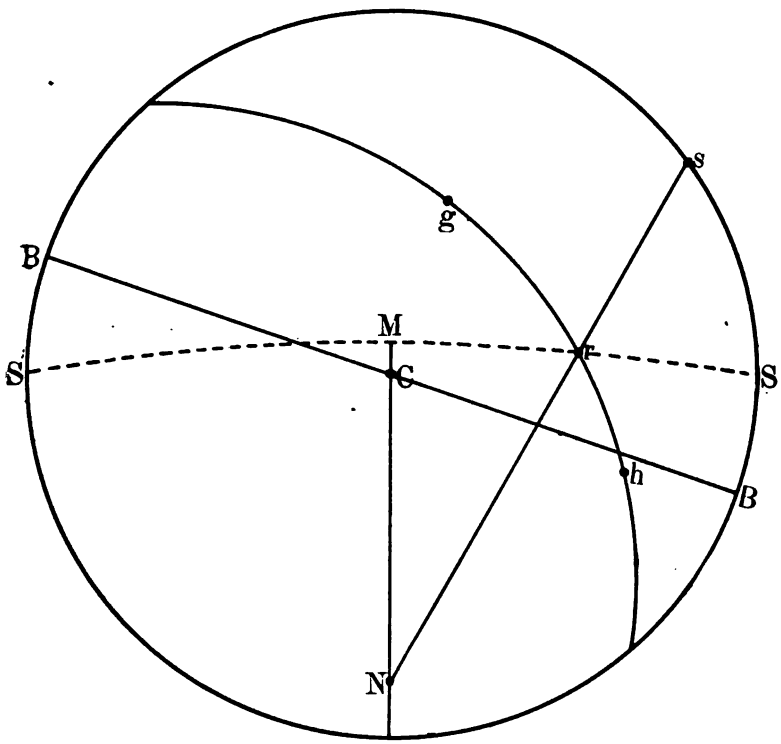

FIG. 1.

In Fig. 1 the zone circle through any two faces, *g* and *h*, intersects the plane of projection *SMS'* in the point *r*. Then a line drawn from *N*, the pole of the plane of projection (90 stereographic degrees from *M* on the line *MC*) through *r* determines the point *s*. A line normal to *Cs* is the desired intersection edge of the faces *g* and *h* in the clinographic projection. Similarly for other faces. For faces that do not appear in the stereographic projection (*i. e.*, those on the lower half of the crystal) faces parallel to them in the upper half are used, *e. g.*, for $hk\bar{l}$ faces use $\overline{hk}l$, for $hk\bar{l}$ use $\bar{h}kl$ etc.

Plate I. is an example of a clinographic drawing of a topaz crystal (*m*, 110; *l*, 120; *c*, 001; *y*, 041; *i*, 223; *p*, 111) with the accompanying stereographic projection from which it was made In this drawing the dotted line represents the plane of projection and the short lines on the equatorial circle represent the normals to the intersection edges of the projection.

One objection that might be raised to the method is that there is required a large number of arcs of zone circles, one for each zone that appears as an intersection edge. This may be obviated by using Penfield's protractor for great circles.* Instead of drawing the zone circles place a straight edge over the drawing with the protractor in the proper position one end at *N*, and the other at the intersection of the plane of projection with the particular zone circle of the protractor. Slip the protractor out and mark on the equatorial circle, its intersection with the straight edge. On Plate I. the direction of the intersection edges of the different faces are thus marked on the equatorial circle.

One great advantage of this method is that nothing need be known of the axial elements or indices in order to make the projection.†

It is believed that this method of drawing crystals is especially advantageous when a number of drawings of crystals of the same substance are required. One stereographic projection suffices for all the drawings of the crystals of a given substance or series of isomorphous substances. The intersection edges can be marked on the equatorial circle and added to when crystals having different faces are to be drawn. A set of stereographic projections of the common minerals thus marked will prove to be exceedingly convenient in drawing crystals.

STANFORD UNIVERSITY,
September, 1906.

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* *Am. Jour. Sci.* (4), 11, 1, 1901.

† In the usual axiometric method confusion may result in reducing Miller indices to the Weiss symbols and also the linear projection must be learned.

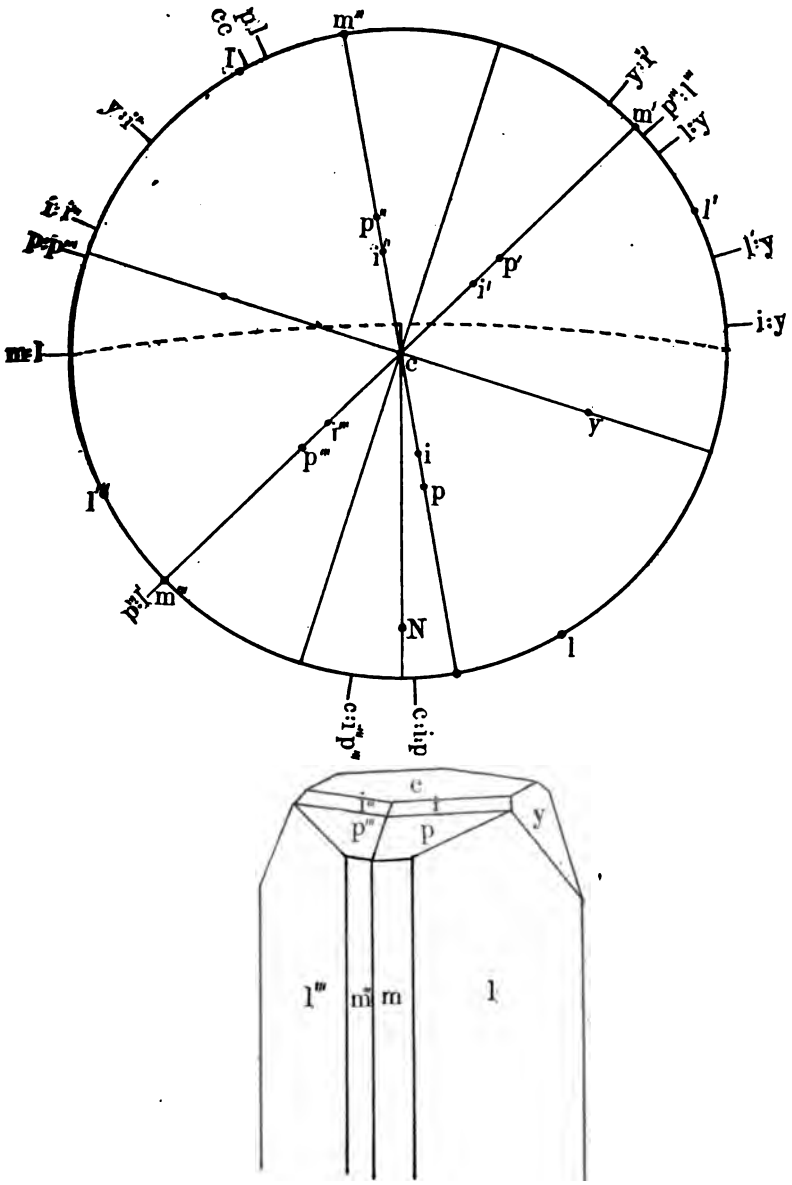

Plate I. STÖBER'S METHOD OF MAKING CRYSTAL DRAWINGS.—ROGERS.

ABSTRACTS.

ANALYTICAL CHEMISTRY.

BY E. WALLER.

Sodium Hydrosulfite in Gas Analysis. Frauzen (*Ber.*, XXXIX., 2069). The reagent has many advantages. Used in slightly alkaline solution it absorbs oxygen readily at even low temperatures, is colorless, and does not take up CO_2. The solution should contain 50 gms. hydrosulfite in 250 cc., to which is added 40 cc. of NaOH solution (containing 500 gms. NaOH in 700 cc.).

The reaction is $Na_2S_2O_4 + H_2O + O = 2NaHSO_3$.

One gm. of the hydrosulfite is capable of absorbing about 64 cc. O_2.

Silver Crucibles for Sodium Peroxide Fusions. Barlow (*J. Am. Chem. Soc.*, XXVIII., 1446). The Ag forms compounds which dissolve in solvents used to take up the melt. Ni crucibles should be used in preference.

Preparing Rubber Samples for Analysis. Baskerville (*J. Am. Chem. Soc.*, XXVIII., 1511). The samples were obtained in pulverulent form by chilling with liquid air, and then grinding under that refrigerant in an ample agate mortar.

Standardizing Permanganate. Hopfgartner (*Wiener Monatsh.*, XXVI., 469). Metallic Ag is quantitatively dissolved by $Fe_2(SO_4)_3$. Hence a weighed amount of pure Ag when heated out of contact with the air (valved flask, etc.), with sufficient iron alum solution of suitable concentration reduces a corresponding amount of Fe to ferrous salt. Thus: $2Ag + Fe_2(SO_4)_3 = Ag_2SO_4 + FeSO_4$.

The solution may then be titrated with the permanganate.

Sodium Phosphates Acidimetric. Ahlum (*J. Am. Chem. Soc.*, XXVIII., 533). With methyl orange indicator the reactions are:

$$HCl + Na_2HPO_4 = NaH_2PO_4 + NaCl.$$
$$2HCl + Na_3PO_4 = NaH_2PO_4 + 2NaCl.$$

Hence 1 cc. of N/10HCl = 0.0142 Na_2HPO_4 or = 0.0082 Na_3PO_4.

If CO_2 is passed into a solution of Na_3PO_4 the reaction is:

$$CO_2 + 2Na_3PO_4 + H_2O = 2Na_2HPO_4 + Na_2CO_3.$$

A method has accordingly been worked out for the determination in a material of the relative proportions of di- and tri-sodium phosphate. Titrate a solution of 1 gm. of the sample directly. The alkalinity indicated is due to both. Then dissolve 2 gms. in water, pass CO_2 for 10 to 15 minutes, evaporate to dryness, and in the dry salts (or an aliquot part thereof, one half, etc.) determine CO_2 (by Schrotter apparatus or other) $CO_2 \times 7.4545 = Na_3PO_4$.

The amount of Na_3PO_4 thus found, divided by 0.0082 for 1 gm. (0.0164 for the 2 gms. taken) gives the number of cc. neutralized by

Na_3PO_4. The remainder was used in neutralizing the Na_2HPO_4 present.

An alternate method depends upon the fact that an acidified solution of alkaline phosphate when boiled with a slight excess of Na_2CO_3 affords a solution of Na_2CO_3 and Na_2PO_4.

Hence the method may be: Titrate 0.5 gm. directly with N/10HCl.

Dissolve also 1 gm. of the sample, add HCl in slight excess, then Na_2CO_3 in slight excess. Evaporate to dryness, and in one half of the mixed and dried salts determine CO_2; on the other half titrate, as before.

From the CO_2 found, calculate the alkalinity attributable to Na_2CO_3.

The remaining alkalinity is due to phosphate at this stage all as Na_2HPO_4.

From the second titration deduct the cc. due to Na_2CO_3. Deduct the remainder from the cc. of the first titration. Double this remainder shows cc. neutralized by Na_3PO_4 in the original (0.5 gm. used) — multiply by 0.0082.

The rest of the cc. in the first titration was neutralized by the Na_2HPO_4. Double this, and multiply by 0.0142. Na_2CO_3 if present in the original, must be determined separately.

Free Acid in Presence of Ferric Salts. Chester Ahlum (*Proc. Lond. Chem. Soc.*, XXII., 63). By addition of sodium dihydrogen phosphate (NaH_2PO_4) Fe is removed from the solution and the ordinary acidimetric titration may be used. A correction must be applied for the amount of acid set free by the reaction which is proportional to the amount of Fe present, *e. g.*, $Fe_2Cl_6 + 2NaH_2PO_4 = 2FePO_4 + 2NaCl + 4HCl$, etc.

Determination of Calcium. Brunck (*Fres. Zts. Anal. Chem.*, XLV., 78). After obtaining the element as CaC_2O_4, the form into which it is converted for weighing may be CaO, $CaCO_3$ or $CaSO_4$. Correct results may be obtained with either though the author prefers the $CaSO_4$. He finds that by addition of HF and heating off the excess of acid, conversion to CaF_2 may be accomplished and much of the inconvenience of the $CaSO_4$ operation can be avoided. With the usual treatment, the CaF_2 is quite as permanent and suitable a form for weighing as any.

Magnesium-Qualitative. Grimbert (*J. Phar. Chem.*, XXIII., 237). Schlagdenhaufen's reagent, sodium hypoiodite (NaIO) is rather unstable. The author proposes the addition of a few cc. of 10 per cent. KI followed by a few drops of NaClO solution. Magnesium if present, gives a red coloration or a brownish precipitate. The reaction is less delicate than the ordinary test with phosphate.

Separating Manganese from Nickel and Cobalt. Funk (*Zts. Anal. Chem.*, XLV., 562). Treatment of the mixed sulphides in the cold with a 0.5 to 1.5 per cent. solution of formic acid will serve to separate Mn but is ineffective with Fe. The NiS and CoS when filtered off, must be washed with H_2S water. The filtrate after neutralization should be treated with H_2S, and the acidification repeated to recover any small amounts of Ni or Co that may have escaped in the first treatment.

Nickel-Qualitative. Reichard (*Chem. Zeit.*, XXX., 556). A very minute amount of a nickel salt with mineral acid, when heated in a white porcelain dish with a little methylamine hydrochloride, gives a

deep blue which fades on cooling. Co salts also give a blue, but the color persists on cooling.

Separating Iron from Zinc. Komar (*Chem. Zeit.*, XXX., 31). Convert to sulphates, oxidizing the Fe with a little HNO_3 if necessary. Evaporate to dryness on the water bath, then heat on the sand bath, finally heat with free flame to dull red. On cooling and treating with water, Fe_2O_3 remains behind, while $ZnSO_4$ which does not decompose at 700° C. or over, will be dissolved out.

Zinc Titration with Ferrocyanide. Murmann (*Zts. Anal. Chem.*- XLV., 174). To have an indicator in the solution and avoid the "spot" test, the author finds that 2 to 5 cc. of a 1 per cent. solution of uranyl chloride will serve in 100 to 150 cc. of solution titrated. (Operation conducted at boiling temperature.) A ferrocyanide solution containing 43.11 gm. per liter is used.

NH_4Cl and most other salts likely to be present have but little disturbing effect. The same may be said for free HCl if the proportion does not exceed 20 cc. (of Sp. Gr. 1.075) in 100 to 150 cc. of liquid. Small amounts of HNO_3 do interfere, which constitutes a reason for the use of uranyl chloride as indicator.

Qualitative for Zinc. Bradley (*Am. J. of Sci.*, XXII., 326). Sodium nitroprusside affords a salmon pink precipitate with Zn which becomes crystalline on cooling in contradistinction to the other metals which afford amorphous precipitates.

The best mode of applying the test appeared to be removal of the Cu by H_2S and then concentrating the filtrate to small bulk, placing a drop on a microscope slide together with a drop of freshly prepared solution of nitroprusside. On cooling, the rectangular plates and prisms of the Zn compound were readily seen.

Delicate Reaction for Copper. Bradley (*Am. J. Sci.*, XXII., 326). A dilute solution of hæmatoxylin was found to be more delicate than the other tests usually applied, indicating one part Cu in a thousand million (dark blue coloration). The limit of sensibility with ferrocyanide was about one in 100,000, and of KI and starch one in a million.

Qualitative for Copper in Presence of Lead or Bismuth. Meerburg and Filippo (*Chem. Centr.*, 1905, II.,1466). Adding CsCl to an HCl solution containing Cu affords red needle shaped or prismatic crystals. If the CsCl is in excess the crystals are yellow. Pb and Bi give colorless compounds Co and Fe interfere.

Small Amounts of Copper in Water. Phelps (*J. Am. Chem. Soc.*, XXVIII., 368). Evaporate 1 liter or other convenient quantity to 75 to 100 c.c., acidulate with H_2SO_4 electrolyse for four hours or more, dissolve off in dilute HNO_3 and determine by color comparison in Nessler tubes, using K_2S as a reagent. The standard Cu solution for comparisons is made up to contain 0.2 mgm. Cu per cc.

Silver in Commercial Copper. (*Eng. and Min. Jour.*, LXXX., 732.) Place 5 gms. of the filings in a scorifier, and stand it in the front end of a muffle. Stir frequently that the Cu may be as fully oxidized as possible. Then cool, treat with 10 per cent. H_2SO_4, which dissolves out the most of the Cu. The residue contains the Au and Ag. Filter

off dry and scorify with 70 gms. test lead and 3 gms. borax glass — and then cupel as usual.

Cadmium Determination. Baubigny (*C. Rend.*, CXLII., 577). To avoid errors liable to occur in weighing as CdS, it is proposed to convert to $CdSO_4$ for weighing, by which means very accurate results may be obtained.

Mercury Ores. Holloway (*Analyst*, XXXI., 66). For low grade ores the amount of ore to be taken depends on its richness. For under 1 per cent. Hg, use 2 gms. If between 1 and 2 per cent. Hg, use 1 gm. and so on. Mix with 10 grms. 60 mesh iron filings and cover with 5 gms. of 30 mesh filings. Set the crucible in a tin plate or asbestos board in which there is a hole only large enough to hold it, that the bottom may be heated by the flame but not the top Cover with two (weighed) plates of clean silver foil, the upper one being a little the larger. Set on top of the covers, a copper or metal vessel through which cold water can be passed to keep the plates cool. Heat for 20 minutes, making only the bottom of the crucible red-hot. Cool for full 15 minutes, dry and weigh the covers. Tarry substances if appearing on the foils may be rinsed off with alcohol before drying.

Volumetric for Lead. Moser (*Chem. Ztg.*, XXX., 9). Especially applicable to sugar of lead. A known amount of KIO_3 is added to solution of the sample, which is then diluted to some definite volume. On filtering off an aliquot portion, and adding KI, any liberation of I at this point may be titrated as giving the measure of the free acid in the sample. Then add H_2SO_4 and titrate (with standard $Na_2S_2O_3$) from which may be found the excess of KIO_3 used, and by subtraction the amount of Pb present.

Gold or Silver—Quantitative. Goldschmidt (*Fres. Zts. Anal. Chem.*, XLV., 87). Ag may be precipitated quantitatively by boiling the solution with a strip of cobalt foil. Gold — by boiling with a strip of nickel in the form of foil.

Assay of Cyanide Solution from Gold Extraction. Stines (*Min. ana Sci. Press.*, April, 1906). To 100 cc. of the solution, add 7 cc. of a 10 per cent. $Pb(C_2H_3O_2)_2$ solution, then 1 gm. Zn shavings and heat, but *not to boiling.* (The aim is to keep the Pb together in one mass of sponge which would be broken up by boiling.) When all Pb is down, add 20 cc. conc. HCl and continue heating until effervescence ceases. By means of a flattened glass rod press the Pb into a scale. Pour off the clear solution and drop the mass into a small cornucopia of sheet lead. Warm for a time to drive off the water and then cupel. The method is much more rapid than evaporation in Pb pans.

Arsenic Separation. Cantoni and Chantems (*Ann. Chim. Anal. Appl.*, X, 213). From a mixture containing As_2O_3, strong HCl, and methyl alcohol, the As may be entirely driven out by passing a current of air at ordinary temperature. If Sb is present, it will readily vaporize by heating the mixture, and can be caught and determined.

Antimony Electrolytic. Laugness and Smith (*J. Am. Chem. Soc.*, XXVII., 1524). To the Sb solution were added 15 cc. Na_2S solution (Gr. 1.18), 3 gms. KCy, 1 cc. of 10 per cent. NaOH and the whole was diluted to 70 cc. When heated nearly to boiling, with a current of 6

amp. per dcm. and 3.5 to 4 volts, with rotating anode, the whole of the Sb was deposited in an adherent coating in 15 minutes The process affords a perfect separation from As.

Separation of Arsenic Antimony and Tin when obtained as sulphides, Qualitative. Materne. (*Bull. Soc. Chem. Belge*, XX., 46.)

A: When Sn is only in stannous form, boiling the mixed sulphides with a 2 per cent. solution of borax containing NH_4Cl, dissolves only As_2S_3, which may be separated from the filtrate by adding HCl. From the remaining sulphides, Sb_2S_3 is dissolved out by boiling with a 5 per cent. solution of Na_2CO_3 containing NH_4Cl.

SnS remains, while Sb_2S_3 may be precipitated from the filtrate by HCl.

B. When the Sn is partially or entirely in the stannic form digest 10 minutes in a 2 per cent. solution of borax containing NH_4Cl which dissolves only As_2S_3. Dissolving the remaining sulphides in a 5 per cent. solution of NaOH, and then heating with tartaric acid and NH_4Cl affords a precipitate of Sb_2S_3, and in the filtrate Sn may be precipitated by HCl.

C. Boiling the mixed sulphides with Na_2CO_3 solution and filtering hot will give a solution containing only As and Sb. On cooling Sb_2S_3 separates and in the filtrate from that, As_2S_3 may be precipitated by HCl.

The methods will serve for quantitative separation of As but not of Sb from Sn.

Separating Antimony and Tin. Czerwek (*Fres. Zts. Anal. Chem.*, LXV., 505). In this process the presence of any Cl compounds is fatal to a perfect separation.

Treat 0.5 gm. of the alloy at 40 to 50° C. with a solution made up with 15 cc. of cone. HNO_3 (Gr. 1.42) and 15 cc. H_2O in which 6 gms. tartaric acid have been dissolved by the aid of heat. Complete solution will require 2 or 3 hours. Heat rapidly to incipient boiling, and then add 5 to 30 drops (according to the amount of Sn present) of 45 per cent. H_3PO_4 (Gr. 1.3). Too large an excess gives trouble in washing the Sb precipitate later. Dilute with about 300 c.c. boiling water, and stand on the water bath to settle.

Filter and wash by decantation, using always *hot* water, containing some NH_4NO_3. Keep the major part of the precipitate in the original beaker. Pour warm $(NH_4)_2S$ through the filter paper, catching the solution in the beaker containing the major portion of the precipitate. Warm to effect solution, then *cool completely*, dilute largely and precipitate SnS_2 with H_2SO_4. (If Cu is present, use Na_2S and filter off the CuS at this point.) Stand on the water bath until the greenish gray precipitate settles well, then filter and wash with water containing NH_4NO_3. Dry on the filter, separate the most of the precipitate from the paper — burn that to ash, then add the precipitate, oxidize with HNO_3 and finally ignite and weigh SnO_2.

Neutralize the filtrate with NH_4OH, add $(NH_4)_2S$ and precipitate with acetic acid, settle on the water bath, filter, etc. The author prefers Bunsen's method. — Evaporating the $(NH_4)_2S$ solution of the Sb in a weighed dish, oxidizing with HNO_3 and heat, and finally igniting and weighing as Sb_2O_4.

Babbitt Metal. Yockey (*J Am. Chem. Soc.*, XXVIII., 646.) Treat 1 gm. of the sample (filings, etc.) with 20 cc. HNO_3 dilute (1:2). Keep

covered until the first vigorous action is over, then remove the cover and evaporate to dryness. Bake 1 hour in air bath at 120°. Moisten with conc HNO_3 then add 30 to 40 cc. hot water and boil five minutes. Filter off mixed SnO_2 and Sb_2O_4 wash with hot water, ignite in porcelain crucible and weigh. Dilute the filtrate to 250 cc. Mix and take 50 cc. for Pb, adding 10 cc. of NH_4OH (1 : 1) and then 6 cc. glacial acetic acid. Heat to incipient boiling, and titrate with standard (NH_3), MoO_4 and tannic acid indicator.

To the remaining 200 cc. add Na_2CO_3 until a precipitate forms, then 1 or 2 cc. NH_4OH. If Cu is present let settle and titrate with standard KCy.

Meantime treat another 1 gm. with 1 gm. KI, 40 cc. conc HCl and 40 cc. H_2O. Boil gently for an hour—and filter off metallic Sb on a weighed or counter-balanced filter. Wash with hot dilute HCl, then with hot water, finally with alcohol. Dry at 100° C. for an hour and weigh. Calculate to Sb_2O_4 and deduct the result from the weight of mixed oxides first found. Calculate the remainder as SnO_2 to Sn.

The method for Sb in this scheme having been subjected to adverse criticism, the author in a subsequent communication (ib., p. 1435) proposes instead of weighing the metallic Sb, to filter through asbestos in a Gooch, wash five or six times with hot dilute HCl, and then to treat asbestos and precipitate in a beaker with 20 to 25 cc. conc. HCl and a few crystals of $KClO_3$ warming gently. After solution of the Sb, dilute to 100 cc., filter out the asbestos, wash, boil out free Cl cool, add 1 gm. KI and titrate with standard $Na_2S_2O_3$.

Tin Qualitative. Reichard (*Pharm. Centrh.*, XLVII., 391). Any stannic compound on treatment with NaOH. and warming with powdered uric acid in a porcelain crucible affords a stain gray to black. Stannous compounds fail to give the reaction.

Commercial Tin. Victor (*Chem. Ztg.*, XXIX., 179). Take 20 gms. if the metal is 99 per cent. or 10 gms. if it is 98 per cent. or less. Dissolve in 100 cc. HCl (of Sp. Gr. 1.124) in a litre Erlenmeyer flask with the aid of moderate heat. When nearly cold add $KClO_3$ in small amount at a time, until the foreign metals are dissolved. Then expel the Cl by long boiling. Meantime dissolve 30 gms. $H_2C_4H_4O_6$ in water, supersaturate it with NH_4OH, add to the solution of the sample, and render the whole mixture *slightly* alkaline with NH_4OH. Then pour into it water at 40° C. which has been saturated with H_2S, until no further precipitation occurs, filter and wash with H_2S water. Digest the washed precipitate for some time with Na_2S solution, to remove all Sn, filter and dissolve in HNO_3. Evaporate down to fumes with H_2SO_4, filter off $PbSO_4$, dissolve same in $NH_4C_2H_3O_2$, add H_2SO_4 and evaporate again to fumes, etc., to obtain pure $PbSO_4$ for weighing. In the filtrate from the Pb separate Bi and Fe by NH_4OH and $(NH_4)_2CO_3$ and in the filtrate from that determine Cu.

For Sb dissolve 10 gms. in HCl as before, oxidize with $KClO_3$, boil out Cl, and dilute largely. Place in a flask provided with a Bunsen valve, add an iron nail and a small amount of ferrum reductum ("Iron by hydrogen"). The metallic Sb is precipitated after about 45 minutes action if the solution is kept moderately warm. After washing off the nail, filter, dissolve in $HCl + KClO_3$ boil out Cl, neutralize with excess of NaOH, add Na_2S and KCy and electrolyze.

In block tins containing 96 per cent. or less, the Sn is determined volumetrically by titration with strongly acid Fe_2Cl_6 solution. The indicator is made by dissolving 10 gms. KI in 10 cc. of water, and adding 10 gms. HI (Sp. Gr. 1.5) containing 3.3 gms. Cu_2I_2. The preparation should stand for some days before using. A few pieces of metallic copper should be introduced, and the mixture should be kept in the dark. When used, it should be clear and colorless. The starch added to the tin solution at the time of titration, will react with the I of this indicator as soon as the Fe_2Cl_6 is in excess. Ten drops of the indicator are used at a time.

The Fe_2Cl_6 solution is made with 275 gms. of the sublimed salt, dissolved in 250 cc. conc HCl, and diluted to 10 litres. 1 cc. should equal 0.01 gm. Sn.

To carry out the process dissolve 5 gms. of the sample with the aid of $KClO_3$ and dilute to 500 cc. Put 50 cc. into a flask with a Bunsen valve, add a little ferrum reductum, and warm 20 minutes on the water-bath. A portion of the Fe should remain undissolved when the reduction of Sn is complete. Filter through asbestos on which a little ferrum reductum has been strewn, and wash with diluted HCl, add to the filtrate 100 cc. conc. HCl, 10 drops of indicator and 1 cc. starch solution. Near the end of the titration add a few drops of the I indicator again to be certain of the end reaction.

Reduction by Al. as preliminary to titration as above is preferable as it avoids filtration. The reduction should be effected in a flask through which a current of CO_2 is passed. After the Al has reduced all the Sn to metal, 50 cc. HCl is added and the metal again brought into solution, when the titration can be performed as described.

Separating Beryllium from Aluminum and Iron. Parsons and Barnes (*J. Am. Chem. Soc.*, XXVIII., 1589). A boiling solution of $NaHCO_3$ was found to be a better reagent for the solution of $Be(OH)_2$, than the $(NH_4)_2CO_3$ usually used. The best method seemed to be to add the (neutral) boiling hot solution of the mixed chlorides to a nearly boiling solution of $NaHCO_3$ containing enough of the salt to make the mixed liquid approximately a 10 per cent. solution. After bringing to a boil which is maintained for half a minute, filter and wash with water containing some $NH_4C_2H_3O_2$. The precipitate should be dissolved in HCl, and reprecipitated to effect complete separation. The filtrate is acidified with HCl, CO_2 thoroughly boiled out and the $Be(OH)_2$ precipitated out by NH_4OH, washing with diluted acetate as before. Some of the precipitate will always adhere to the beaker, and should be dissolved off with HNO_3 and recovered.

Analysis of Mantles for Incandescent Lights. Stillman (*Chem. Ztg.*, XXX., 60). Five mantles are calcined, broken up and heated in a platinum capsule with conc. H_2SO_4. Heat to dryness, take up with water, and if there is any insoluble residue, fuse with $KHSO_4$ and dissolve in water. Add NH_4HS which precipitates Ce, Th, La, Zr, Al, Di and Yt. Filter and wash with water containing NH_4HS. The solution contains Ca and Mg.

Dissolve precipitate in HCl, dilute, boil 1 hour with dilute $Na_2S_2O_3$, keeping the volume up. Let stand 12 hours, and filter.

Precipitate *A*. (Th, Zr, Al.) Dissolve in HCl, either directly, or after fusion with $KHSO_4$, precipitating Th by NH_3 and redissolving in HCl. Add excess of $Na_2S_2O_3$, boil, filter, wash with water, redissolve in HCl, boil 5 minutes with excess of oxalic acid, filter after standing 12 hours.

Precipitate *B*. Wash, dry, ignite and weigh as ThO_2. No spectrum.

Filter *B*. Supersaturate with NaOH, heat 10 minutes, filter and wash with boiling water.

Precipitate *C*. Dry, ignite and weigh as ZrO_2. No spectrum.

Filter *C*. Acidulate with HCl, add NH_3 in excess, heat, filter, wash, and ignite, weigh as Al_2O_3. No spectrum.

Filter *A*. Add NH_3, filter, wash, dissolve in HCl, and eventually separate a little ThO_2 held with it. Precipitate with NH_3 redissolve in H_2SO_4, expel excess of acid, dissolve in water, add concentrated solution of K_2SO_4, let stand 4 hours, filter and wash with saturated solution of K_2SO_4.

Precipitate *D*. Dissolve in HCl, precipitate by oxalic acid, filter, dry, ignite, redissolve in HCl, add NaOH in excess, wash, dry, calcine, weigh as $Di_2O_4 + La_2O_3$.

Prove the presence of La by precipitating solution of the nitrates by NH_3 and ammonia acetate. Treat the precipitate with solid I, which gives a blue coloration.

Solution *D*. Add dilute NaOH to alkalinity, filter, wash with water, dry, calcine, weigh as Y_2O_3.

Extracting Thorium from Monazite Sand. Garelli. International Congress of App. Chem. at Rome (*Zts. f. angew. Chem.*, XIX., 895). The author fuses with Na_2O_2 or with $NaClO_3$ and $KClO_3$. Ce is obtained as CeO_2. The mass is then treated with H_2SO_4 and the solution warmed with NH_4OH. Ce and Th are thus precipitated. Then treat with $H_2C_2O_4$. The resulting Th and Ce can then be separated by salicylic acid or by use of $Na_2S_2O_3$.

Separating Vanadium and Uranium. Feim (*J. Am. Chem. Soc.*, XXVIII. 1443). Treat an amount of ore not containing over 0.25 gm. U_3O_8 with H_2SO_4 (1 : 5) and evaporate to fumes. Cool, dilute, add excess of Na_2CO_3 and boil until the precipitate settles well. Filter and wash with hot water. Dissolve in as little H_2SO_4 as possible, and repeat the precipitation. Acidify combined filtrates and wash waters with H_2SO_4, add about 0.5 gm. $(NH_4)_2HPO_4$, bring to a boil, and then make alkaline with NH_4OH. Boil a few minutes, filter UO compound, and wash with water containing $(NH_4)_2SO_4$.

Acidify the filtrate with H_2SO_4, reduce with SO_2, boil out excess, and titrate hot with standard permanganate Fe factor $\times$ 1.631 = V_2O_3 or $\times$ 0.9159 = V.

Dissolve the precipitate in H_2SO_4 — add granulated Zn and allow the action to continue at least 30 minutes. Filter out undissolved Zn through asbestos, and titrate at about 60° with standard permanganate. Fe factor $\times$ 2.5167 = U_3O_8 or $\times$ 2.133 = U.

Colorimetric for Selenium. Clenell (*Chem. Zeit.*, XXIX., 392). Obtain as selenite or selenate by use of conc. HNO_3. Boil out any free Cl, add a few cc. of 5 per cent. solution of $NaHSO_3$. The suspended Se is very fine and takes a long time to settle. For comparison solution use 0.1 gm. Se dissolved in Br water, adding $NaHCO_3$ until colorless, and treating with $NaHSO_3$.

Separating Tungsten from Tin. Donath (*Zts. angew. Chem.*, XIX., 473). The author republishes his method (originally published 1887). The mixed oxides (SnO_2 and WO_3) are mixed with zinc dust and ignited for about 15 minutes in a covered porcelain crucible. On cooling the spongy mass is treated in beaker with dilute HCl (1 : 2) until no more H is evolved (Sn all dissolved). Cool somewhat, and add cautiously powdered $KClO_3$ until the blue W_2O_3 is oxidized to yellow WO_3. Dilute with at least 1½ volumes of water — allow to stand 24 hours, filter off the WO_3, wash first with water acidified with HNO_3, finally with a hot dilute solution of NH_4NO_3. Washing with pure water affords turbid filtrates. Dry, ignite and weigh WO_3. In the filtrate precipitate Sn by H_2S in the cold.

Tin and Tungsten. Angenot (*Zts. angew. Chem*, XIX., 140). Ores containing these two elements should be finely pulverized and intimately mixed with 8 times their weight of Na_2O_2 in an iron crucible. Heat up carefully until the mass is fluid, and maintain this condition for about 15 minutes, moving the crucible somewhat to stir the contents. Cool, take up with water (if Pb in present pass in CO_2) dilute to 250 cc., and then filter off two lots of 100 cc. each.

One lot (for W) is run into a mixture of 15 cc. conc. HNO_3 with 45 cc. conc. HCl, evaporated in a porcelain dish until "dust dry." The residue is treated with a solution containing 100 gm. NH_4Cl and 100 gm. conc. HCl per liter. The insoluble portion is dissolved in warm ammonia, run this solution again into a solution of 15 cc. HNO_3 with 45 cc. HCl as before, and again evaporate, and treat as before. The insoluble portion after washing is pure WO_3.

To the other lot (for Sn) add 40 cc., conc. HCl which precipitates WO_3 and SnO_2 then add 2 to 3 gms. pure Zn. Allow to stand at 50 to 60° for an hour. Sn will have passed into the form of $SnCl_2$, the major part of the blue W_2O_5 being in an insoluble form. Filter, and in the filtrate precipitate Sn by H_2S. The remainder of the treatment needs no further directions. To insure avoidance of loss of Sn as metal in the residue — dissolve off the W_2O_5 from the filter by warm NH_4OH. If any metallic particles remain, dissolve in HCl and add to the main solution

Osmium from Other Platinum Metals. Orlow (*Chem. Zeit.*, XXX., 714). Precipitate all the metals by addition of metallic Zn or Mg to the solution. On treating the mixture of metals thus precipitated with H_2O_2, Os only dissolves.

Chlorate in Sodium Nitrate. Grimbert (*J. Pharm. Chim.*, XXIII., 98). A drop of aniline is added to a small amount of the solution, and then some conc H_2SO_4 is poured down the side of the tube. If chlorate is present a blue zone appears at the line of contact of the liquids. For quantitative determination add a little cane sugar to some of the sample, ignite, then cool, extract with water and determine as chloride.

Iodine in Mixtures of Halogen Salts. Jaunasch and Zimmerman (*Ber.*, XXXIX., 196). Dissolve in 120 to 150 cc. water, add 15 cc. pure glacial acetic, and at least 3 cc. of Mercks 30 per cent. H_2O_2. Then distil in a current of steam. I only passes over. The main receiver should contain 80 to 100 cc. water, 10 gms. crystallized hydrazin sulphate and 10 cc of the strongest ammonia. In the Peligot bulb tube used as a

guard beyond the main receiver, 25 cc. water, 2 cc. conc. NH_4OH and 0.5 gm. hydrazin sulphate.

The solution decolorizes after heating 3 to 5 minutes, but the distillation should be continued for 20 to 25 minutes. Finally rinse the receivers into a beaker, add 30 to 40 cc. conc. HNO_3 and precipitate with $AgNO_3$, keeping the solution warm until the solution clears before filtering.

Fluorides-Etching Test. Woodman and Talbot (*J. Am. Chem. Soc.* XXVIII., 1437). The method for separating the F for testing is that described in United States Department Agriculture, Circular 28, of Bureau of Chemistry. 150 cc. of the solution receives the addition of 10 cc. K_2SO_4 (33 gms per litre) and when heated to boiling a further addition of 10 cc. of a 10 per cent. solution of $Ba(C_2H_3O_2)_2$. After boiling a moment, the precipitate is allowed to settle, when it is filtered off, and ignited in a platinum crucible. A few drops of conc. H_2SO_4 are added, and a cleaned glass plate coated with a mixture of paraffin and carnauba wax is made to adhere to the top of the crucible by warming the crucible and pressing into place, a portion of the wax having been, of course, scraped off so as to make a recognizable design. For comparison tests the area of glass exposed to the action of the vapors should be as nearly as possible the same. The cru ible is set in a hole in asbestos board and heated with a low flame. A few drops of water are put on the upper side of the glass, and against it is pressed a condenser made of a filtering tube with 3-way tube attached to its stem the open end being closed by thin sheet rubber tied tightly about the tube. After running for an hour, the glass is cleaned off, polished and examined for etching. It was found that approximately quantitative estimations could be made by regulation of the temperature to which the crucible is heated. At 79° to 82° between 1 in 25,000 and 1 in 100,000 showed etching, at 113° between 1 in 100,000 and 1 in a million, etc.

Qualitative for Borax. Reichard (*Chem. Centr.*, 1906, 1, 1714). A mixture of borax and alpha nitroso betanaphthol when moistened with cold water shows a bright green color. An excess of B_2O_3 prevents the reaction.

Boric Acid. Manning and Lang (*J. S. C. L.*, XXV., 397). The material is acidified with dilute H_2SO_4, methylated spirit is added in considerable excess, and the mixture distilled into concentrated solution of $BaCl_2$. On exactly neutralizing this distillate $Ba(BO_2)_2$ separates, which may be washed with alcohol, dried and weighed.

Silicon in Presence of Silica. Philips (*Zts. Angew. Chem.*, XVIII., 1969). Igniting and treating with HF gives erroneous results, the Si being also attacked by this treatment. The method proposed is heating with a 30 per cent. KOH solution and measuring the evolved H in the eudiometer.

Sulphur in Pyrites. Gyzander (*Chem. News*, XCIII., 213). By addition of hydroxylamine hydrochlorate to reduce the Fe, and then precipitating with $BaCl_2$ a precipitate free from Fe can be obtained.

The author treats 0.2 gm. of the sample with 5 cc. conc. HCl and 15 cc. conc. HNO_3. Evaporate to dryness, moisten with water, add 5 cc. HCl and evaporate again. When dry the second time add 100 cc. water, 1 cc. conc. HCl and 3 cc. hydroxylamine hydrochlorate (1 oz. in 500

cc.). When the solution comes colorless, filter and wash with hot water. Heat to *near boiling* and precipitate with 10 cc. of a 10 per cent. $BaCl_2$ solution. The precipitate is in somewhat finer state of division than in Lang's method.

Sulphur in Pig Iron. Evolution method McFarlane and Gregory (*Ch. News*. XCIII., 201.) Mix 5 gms. of the powdered sample with 0.5 gms. cream of tartar, wrap the mixture in filter paper, place in a small crucible and heat to bright redness for 15 minutes. Powder the mass by crushing carefully in a glass mortar, and transfer to the evolution flask, the delivery tube of which dips into 25 cc. of a $CdCl_2$ solution (20 gms. $CdCl_2$ in 1 litre of water, with 1 litre strong ammonia added). Run boiling HCl(2:1) into the evolution flask. When the reaction becomes quiescent, boil out all H_2S. Acidify the solution containing the suspended CdS, with HCl, and titrate immediately with standard I solution — best standardized on a steel of known sulphur content.

Sulphide in Commercial Cyanide. Williams (*J. Chem. Met. and Min. Soc. S. Afr.*, VI., 170). Dissolve two separate portions 5 gms. each in 100 cc. each of water previously boiled. To one add 0.5 gm. white lead — shake well and filter. This serves as a comparison solution. Prepare a solution of $PbO.K_2O$ by dissolving PbO in a 5 per cent. solution of NaOH. Add 1 cc. of this solution to each. Then use a standard solution of Na_2S (1 cc. = 0.001 gm. S) adding it from a burette to the clarified solution until the tints (in Nessler tubes) are matched.

Sulphur Acids. Hubener (*Chem. Ztg.*, XXX., 58). To determine the different S acids in a mixture of Na_2SO_4, Na_2SO_3, $Na_2S_2O_3$ and Na_2S, digest a weighed amount of the salts with $CdCO_3$. Only Na_2S reacts with this, affording CdS. Filter off, oxidize and determine as $BaSO_4$. Divide the filtrate into three parts. Titrate one part direct with standard I solution. This gives Na_2SO_3 and $Na_2S_2O_3$. A second part is treated with dilute H_2SO_4 the evolved SO_2 being carried over by a current of CO_2 into a solution containing a known amount of I. By titrating the surplus I and combining the results, the proportions of Na_2SO_3 and $Na_2S_2O_3$ are found. The third portion is oxidized by I and then precipitated with $BaCl_2$ which gives Na_2SO_4 originally present as well as that from oxidation of Na_2SO_3.

Sulphates in Potable Water. Raschig (*Zts. Angew. Chem.*, XIX., 334). Use 0.5 to 5 litres of the water according to the degree of freedom from salts, and add one twentieth of its volume of a concentrated solution of benzidin. Stir, let stand 15 minutes, filter and wash with very little water, and titrate with tenth normal NaOH (1 cc. = 0.004 gm. SO_3). Add to the result 0.0015 gm. SO_3 for solubility of the benzidin sulphate.

Nitric Acid in Nitrates. Bornwater (*Chem. Centr.*, 1906, 1,703). The aluminum method is recommended as expeditious and accurate. It is advised to use an 800 cc. Erlenmeyer flask in which is placed 0.5 gm. of the sample dissolved in 200 cc. of water. Then add 5 cc. alcohol, 50 cc. of KOH (Gr. 1.3) and 2.5 gms. of Al wire. Connect by means of a bulbed tube, with a condenser — heat gently until effervescence ceases; then distil over into standard acid and titrate back.

Color Tests for Nitric Acid. Reichard (*Chem. Ztg.*, XXX., 790). Evaporate some of the solution to dryness, and then add a little arbutin

and a drop of conc. H_2SO_4. HNO_3 affords an intense yellow coloration.

Berberine hydrochloride is more delicate. A drop of the solution to be tested, with a little berberin hydrochloride and a drop of conc. H_2S gives a deep reddish brown coloration.

Nitrates and Nitrites. Busch (*Ber.*, XXXIX., 1401). In acid solution at about 60° to 70° C., H_2O_2 oxidizes nitrites almost immediately to nitrates. If a solution containing both nitrates and nitrites is divided in halves, in one the nitrate may be determined directly by means of nitron acetate (vid QUARTERLY, XXVI., 425, and XXVII., 255) and in the other half the nitrite can be oxidized to nitrate by H_2O_2 and the two determined as nitrate by nitron acetate. Thus: the solution (50 cc.) which should contain 0.1 to 0.2 gm. nitrite receives the addition of 20 cc. of a 3 per cent. neutral solution of H_2O_2, warm to about 70° C., then run into the bottom by means of a dropping funnel, 20 cc. of 2 per cent. H_2SO_4. Heat nearly to boiling and precipitate with 12 cc. of nitron acetate solution. The process is especially useful in analyzing nitrocelluloses, which on treatment with alkali, always afford some nitrite as well as nitrate.

Nitrogen in Nitrocellulose. Busch (*Zts. f. angew. Chem.*, XIX., 1329). Treatment of nitro compounds with caustic alkali, affords nitrate and nitrite and then addition of H_2O_2 oxidizes the nitrite to nitrate, in which condition it can be readily determined by use of "nitron" as a precipitant (vid QUARTERLY, XXVI., 425.) Treat 0.2 gm. of the nitrocellulose in a flask with 5 cc. of a 30 per cent. NaOH solution, and 10 cc. of 3 per cent. H_2O_2 solution, warm a few minutes on the water bath, until the first effervescence is past, then boil over naked flame; solution usually occurs in a few minutes. Then add 40 cc. water and 10 cc. H_2O_2 solution and when at about 50° C. by means of a pipette run 40 cc. of 5 per cent. H_2SO_4 at the bottom of the vessel. Warm to about 80° C. and add 12 cc. of solution of "nitron" acetate (10 per cent. solution of "nitron" in 5 per cent. acetic acid), cool, and allow to stand 1½ to 2 hours cold, preferably in ice water. Filter, wash with 10 cc. of ice water in three or four portions. Dry for 45 minutes at 110° and weigh.

Titration of Hydrogen Peroxide. Mattheson and Calvin (*Amer. Chem. Jour.* XXXVI., 113). The coloration produced by H_2O_2 in TiO_2 solutions can be used as an indicator in the titration of dilute H_2O_2 solutions (added from a burette) against ferrous ammonium sulphate (Mohrs salt).

The H_2O_2 solution should be diluted with known amount of water until the strength is about 0.3 per cent. Then weigh out 2 gms. of the Mohrs salt, dissolve, add a few gms. of $(NH_4)_2SO_4$ and some H_3PO_4. Then add some of a clear solution obtained from the fusion of TiO_3 with $KHSO_4$, and run in the H_2O_2 solution from a burette.

The method can be applied also to the titration of nitrite solutions with H_2O_2. In that case the acid Ti indicator is likely to set free some N_2O_3. The error so produced may be minimized by making first an approximate preliminary titration, and then a second, in which the indicator is not added until nearly all of the nitrite has been oxidized.

Estimating Moisture. Dupré (*Analyst.* XXXI., 213). Place a weighed quantity in a tube about 1 cm. diameter and 12 cm long. Cover with a layer of sand and then add a 5 cm. layer of pulverized calcium

carbide. Connect with a gas burette containing saturated solution of NaCl. Adjust the levels, then immerse the tube containing the sample to a depth of about 8 cm. in a boiling water bath, keeping it there so long as any gas is evolved. Cool to the original temperature, adjust the levels and read off the amount of acetylene formed. Theoretically 1 cc. acetylene = 0.00162 gm. H_2O. Practically, on account of retention of some H_2O by the Ca $(OH)_2$ the figure is 0.001725. The method can be used for determining H_2O in crystallized salts, etc.

"Volatile Combustible" in Coal. Sommermeier (*J. Am. Chem. Soc.*, XXVIII., 1002). Differences in the fineness of pulverization of the coal showed lower results for volatile carbon the more finely the sample was pulverized. The 7 minute ignition also gave higher volatile C the wetter the coal. In some cases the undried coal was ignited directly, in some moisture was added to note the effect. In the case of some lignites there was evidently much mechanical loss of fine particles of the fuel, in one a difference of 20 per cent. in apparent volatile C. The mode of heating whether 7 minutes strong ignition, or four minutes low heating, and three minutes of strong ignition, also gave materially different results.

Melting Point of Asphalt, Pitch, etc. Kraemer and Sarnow (*per. Fres. Zts. Anal. Chem.*, LXV., 458). Fuse a layer of the material about 10 mm. thick in a metal vessel by immersion in an oil bath. Dip into it a glass tube of 6 to 7 mm. bore and about 10 cm. long, withdrawing it, closed with the finger so as to obtain a plug of the material in the lower end. Cool, and then introduce on top of the plug about 5 gms. metallic Hg. Immerse the end so arranged in a saturated solution of NaCl, and place close by it in the solution a thermometer, surround the beaker containing this solution with a paraffine bath, and raise the temperature slowly. The temperature at which the Hg breaks through the plug of pitch or asphalt is the melting point.

Furnace Gases. Didoff and Kusnezoff (*J. Russ. Phys. Chem. Soc.*, XXXVII., 940). By the ordinary methods CO_2, CO, and O_2 may be determined, leaving a residue of H_2, N_2 and hydrocarbons. Passing this residual gas over metallic Mg heated to redness, affords all the H in gaseous form, while the increase in weight of the Mg consists of C and N. By use of the Kjeldahl method the N may be determined, and the C obtained by difference. CH_4, C_2H_4, C_2H_2, etc. are decomposed by the hot Mg.

ALUMNI AND UNIVERSITY NEWS.

SIR WILLIAM HENRY PERKIN.

On Monday, November 5, the degree of doctor of science was conferred, by the Trustees of Columbia University, *in camera*, upon Sir William Henry Perkin, the distinguished English chemist, who was visiting this country as the guest of the chemists of America.

Sir William was presented by Dr. Charles F. Chandler, Mitchell Professor of Chemistry, in the presence of the trustees, the university council and the officers of the chemical department.

This degree was conferred by President Butler in the following form:

William Henry Perkin, Knight — to whose knowledge and insight it has been granted to open a new era in the history of human industry and to show the way to innumerable applications of science to human affairs — I gladly admit you to the degree of doctor of science in this university and confer upon you all the rights and privileges that belong thereto, — in token whereof I hand you this diploma.

Following is Dr. Chandler's speech of presentation:

Mr. President, Gentlemen of the Board of Trustees and University Council and Fellow Professors:

It is a great privilege to be allowed the honor of presenting for a degree from Columbia University so distinguished a chemist as Sir William Henry Perkin.

At the age of twelve Sir William first became interested in chemical experiments, and he began to experiment by himself. Soon afterwards he was sent to the City of London School, where he assisted the lecturer in preparing his experiments. At the age of fifteen he entered the laboratory of Professor Hofmann and began the systematic study of chemistry, much to the disappointment of his father, who had hoped to make an architect of him. He soon completed the courses in qualitative and quantitative and gas analysis and at seventeen was made honorary assistant by Professor Hofmann, in his research laboratory, where his ambition found full scope. He had fitted up a little laboratory at home, and allowing his mind to dwell upon the possibility of preparing the alkaloid quinine artificially, he made his first experiment at the age of eighteen, while at home during the Easter vacation in 1856. In his first experiment he met with no success, obtaining a reddish-brown precipitate. For a second experiment he selected aniline, then hardly more than a chemical curiosity, prepared from indigo. This in the form of sulphate he treated with potassium bichromate, as an oxidizing agent. But instead of obtaining anything that could lead to quinine, he produced a black unpromising precipitate, with some other products of decomposition. Almost every other chemist, young or old, would, at that date have thrown the products away and have abandoned that line of experiment. But the boy Perkin was not the average chemist even at eighteen. He did not throw the results away, but he investigated them and discovered

the black powder to contain a most beautiful purple dye, to which he gave the name "mauve."

To-day the discovery of a new purple-dye would not cause a ripple of excitement in the chemical world, for since Perkin's mauve was created fifty years ago hundreds of purple dyes of all possible shades have been produced. But in 1856 the list of available dye-stuffs was a very short one — madder and one or two other roots, logwood and half a dozen other woods, two or three barks, two or three flowers, one or two berries, two or three entire plants as indigo, weld and lichens, and two bugs, cochineal and kermes, constituted all the organic dye stuffs at the disposal of the dyer. It is true he supplemented these with a few metallic compounds, such as Prussian blue, ultramarine, chrome yellow and chrome green, etc.

To-day, thanks to the way pointed out by Perkin, the chemist supplies him with a choice of some thousands of the purest synthetic dye stuffs, of every color and shade of the rainbow.

But fifty years ago the dyer was a very conservative individual and he saw at first no promise in Perkin's mauve.

The first task was to convince the employer of the beauty and advantage of the new dye. This accomplished Perkin still found it impossible to induce any one to advance even a little capital for putting up even a small factory. Finally his father, having great confidence in the skill and judgment of his son, jeopardized almost all of the moderate savings of a lifetime in the venture, and his elder brother gave his services as business manager, and thus the first coal-tar chemical works the world had ever seen was set up at Greenford Green and mauve was supplied for silk dyeing in December, 1857.

This is not an appropriate occasion to enlarge upon the development of this new branch of chemical industry. Suffice it to say that it has grown to the most extraordinary magnitude. Hundreds of other chemists turned their attention to the subject, and colors of every shade were discovered, each to be carefully tested as to its value as a dye, and its cost of production.

Perkin's works grew to great size, and Perkin himself by his constant research added some of the most valuable novelties. He was especially successful in devising a process for the commercial production of alizarine, and discovered its companion anthrapurpurine.

The French and the Swiss at an early day embarked in the manufacture of coal-tar dyes, but the Germans have far outstripped all other nations in this industry, producing now probably four-fifths of all the products, supplying probably one hundred millions of dollars worth each year; the great companies dividing from 20 to 33 per cent. profits on their capital.

Dr. Perkin discontinued the business in 1873 and has devoted all his energies since that time to original research, of the most interesting and valuable character.

The loss of this industry to England has been a most serious blow and the causes which have led to it have been most carefully studied. Some observing American has said that one of the most serious faults of the English manufacturer is the absence of a scrap heap at his works, the scrap heap being the pile on which the enterprising American throws his old machinery, as soon as he discovers that he can replace it by better. But in this case there is another reason. The English manufacturer never

fully appreciated the value of scientific research — the German did. The Germans when they entered the field of coal-tar industry did everything to encourage chemical research. They established research laboratories in the works, provided every facility for investigation, and relieved their more promising chemists of all the ordinary drudgeries of works chemists. At the same time the technical schools and universities did every thing possible to encourage chemical research, relieving the teachers as much as possible of administrative and executive work, and cutting down the number of lecture hours to a minimum, in order that the chemical instructors might be able to devote the greater part of their time to research.

In the summer of 1905 I visited the famous works of Beyer & Company at Elberfeld, and found over 200 chemists employed there, all doctors of philosophy from the German universities. They were paid moderate living salaries, and given every encouragement and facility for original investigation. Whenever one of them discovers anything valuable he is allowed a fair percentage of the profits. This is the secret of Germany's prosperity in the chemical industries.

But I have strayed away from my subject, in developing the great pioneer discovery of Sir William Perkin. Like Columbus he had discovered what may be likened to a new world in chemical science, and while he continued to explore it himself most industriously, making many most valuable discoveries, some in pure chemistry, others in applied chemistry, a host of other chemists were attracted by his brilliant discoveries, and explored the same region. Chemical science expanded marvelously from this work, and organic chemistry may be said to have become a new science, while inorganic chemistry advanced at almost equal pace.

Sir William Henry Perkin's discovery at the age of eighteen constituted the beginning of a new epoch in the history of chemistry. It not only revolutionized the arts of dyeing and calico printing but it directed the attention of chemists to new fields of investigation, and gave them new methods for building up chemical compounds. The study of chemistry became so much more attractive that the profession rapidly grew in numbers. Chemical societies were established in London, Berlin, Paris, St. Petersburg and the United States, to encourage investigation and afford opportunities for discussion and publication.

While the science of chemistry expanded wonderfully, its value to mankind became more marked. A thousand new remedies were created, chiefly from coal-tar, for the relief of suffering and cure of disease; new antiseptics and disinfectants were discovered; the most valuable of the natural dye-stuffs, alizarine and indigo, were made artificially, thus releasing vast areas of land which had been devoted to their cultivation, rendering it available for food stuffs, and diminishing the danger of famine even in countries as remote as Bengal. The perfumes of flowers were produced synthetically, new developers were provided for the photographer, the wonderful sweetener saccharine was discovered, and no one can predict what wonders are yet to come.

Fifty years having elapsed since Sir William made his epoch marking discovery the chemists of the world have united in doing him honor. Committees of chemists have been appointed in every civilized country to represent their fellow chemists. His Majesty King Edward VII. conferred the order of Knighthood on Dr. Perkin.

A grand jubilee was held in London lasting for two days. First there

was a gathering of the most distinguished chemists in the world in the theatre of the Royal Institution on the morning of July 26. Professor Emil Fisher, representing the Chemical Society of Berlin, presented to Sir William the Hofmann medal. Professor A. Haller, for the Chemical Society of Paris, presented the Lavoisier medal. Addresses of congratulations were presented by representatives of the chemical societies of the United States, Austria, Holland, Switzerland and Bavaria. Lord Kelvin presented an address for the Royal Society.

In the evening a grand jubilee banquet was given, attended not only by the distinguished chemists, but by many others, as Lord Alverstone, Lord Chief Justice; Rt. Hon. R. B. Haldane, Secretary of State for War; Rt. Hon. Lord Justice Fletcher Moulton; Lord Rayleigh; the Earl of Halsbury, and many others.

On Friday, the twenty-seventh, Sir William received the chemists at his country home at the Chestnuts, in Sudbury, affording them an opportunity to stop on their way at the Greenford Green works. In the evening Sir William gave a soiree at the Leathersellers Hall in London.

To perpetuate the memory of this great event, a bust of Sir William was made by the leading English sculptor, to be preserved in the rooms of the London Chemical Society, and a portrait was painted to be placed in the National Portrait Gallery. Further, a substantial fund has been collected to be known as the Perkin Research Fund.

The chemists in America have not failed to do their part in honoring Sir William.

On October 6 a jubilee banquet was held in New York attended by four hundred chemists and distinguished guests.

A Perkin gold medal was established to encourage investigation in industrial chemistry.

A token was presented to Sir William as a reminder of the affection of the American chemists, and a Perkin chemical library is to be established to commemorate his name.

No other chemist of this or any other country or age has ever been so honored. Well might the head of any man be turned by such universal homage. But not our modest, simple hearted Sir William. He takes very little credit to himself. Let me close my remarks by quoting the closing sentence of Sir William's address at the New York banquet: "I, therefore, can only say in reference to the success which has attended my efforts, Not unto me, O Lord, not unto me, but unto thy great name be all the praise."

DEPARTMENT OF GEOLOGY.

During July Professor Kemp was a member of an international commission of geologists appointed jointly by the U. S. Geological Survey, the New York State Survey and the Geological Survey of Canada. The object was to establish the correlation of the Precambrian crystalline rocks in Canada and the Adirondacks and to adopt a uniform series of names. Professor Kemp first guided the party in the eastern Adirondacks; then Professor Cushing (who was a graduate student in the School of Mines, 1882–1883) of Adelbert College, conducted it in the northern and northwestern mountains; and finally Professor Adams of McGill University, was the leader during a two weeks camping trip in Ontario.

In August Professor Kemp sailed for Mexico to attend the Tenth International Geological Congress, where he represented Columbia University and the New York Academy of Sciences. This gathering of geologists from all parts of the world takes place once in three years. Two or three hundred delegates were present from all the countries where the science is cultivated. After ten days of sessions in the City of Mexico, an excursion of three or four thousand miles throughout northern Mexico in special trains and lasting three weeks was given. The great mining districts were especially visited. On the excursion and at the points mentioned Professor Kemp had enjoyable visits with Spaulding, '95, and and Prentis, '06, in Pachuca and Real del Monte; with McClintock, '98, at Mapimi; Reckhardt, '84, at El Paso; Ludlow, '78, in Esperanzas; Dwight, '85, and Yrizar, '95, in San Luis Potosi; Rodriguez, '03, in Mazapil; Raymond, '89, Main, '95, and Enos '06, in El Oro; Parega, '83, and Pitner, '05, in Mexico City. Additions to our collections were secured in many places which will be of much value in instruction.

The field session with the mining engineers was carried on last summer, the week before commencement, with Fishkill on the Hudson as a center. The Poughkeepsie quadrangle was covered by the party and was found to be extremely instructive. The old Archean rocks of the Highlands on the south and the Cambrian and Ordovician on the north furnished many interesting points. The glacial deposits, the problems of drainage and the development of topography were all most instructive.

Dr. Berkey has continued his work in the Highlands of the Hudson, and, having completed the Tarrytown quadrangle for the N. Y. State Geological Survey, has done also the greater part of the areal mapping of the West Point. Both he and Professor Kemp have done much work in connection with the new water supply for the city from the Catskills.

Professor Grabau spent eight weeks in the Southern Appalachians studying the stratigraphy of the Black Shale, under a grant from the Hermann Fund of the Scientific Alliance of New York. He reached some interesting conclusions which will be published during the winter, and brought back a series of rocks and fossils illustrating the stratigraphy of the regions studied. In May, 1906, he was awarded the grand Walker prize in Natural History by the Boston Society of Natural History for his essay on the "Interpretation of sedimentary formations by the principle of progressive overlap." This paper is now being published. Part II. of North American Index fossils Molluscoidea is now passing through the press.

At the Ottawa meeting of the Geological Society of America in January last, Professor Grabau presented two papers: (1) Types of sedimentary overlap; (2) discovery of the Schoharie fauna in Michigan.

BOOK REVIEWS.

The Mineral Industry, its Statistics, Technology and Trade, during 1905. Vol. XIV. Edited by WALTER RENTON INGALLS, Editor of The Engineering and Mining Journal. Published by The Engineering and Mining Journal (Incorporated), New York and London, 1906. 739 pp. Price, $5.00.

As indicated by its title "The Mineral Industry" has three purposes: (1) To afford a condensed view of the yearly statistics of production and consumption of the useful minerals; (2) to trace the course of their development, together with notes on the progress of mining and metallurgy; (3) to present monographs and reviews of new or improved methods.

In the introduction the editor calls attention to the manifold difficulties attending the collection of accurate statistics. Some industries are greatly subdivided, so that reports as to their mineral products in the various stages are apt to cause confusion and errors in the totals. Not infrequently no complete records are obtainable, and embarrassment may be caused by unwillingness on the part of producers to furnish figures. Moreover, returns from foreign countries are often slow and inaccurate. Where statistical tables are carried forward year by year, therefore, the figures given in the latest volume are of course the ones to be used, because corrections of those previously printed have frequently to be made, in the light of later returns. It is due to those who are responsible for the information given, that readers should keep in mind the difficulties involved in the preparation of a work of this kind.

The contributors to the present issue include many well-known mining engineers and metallurgists. L. S. Austin writes on the Progress in the Metallurgy of Copper in 1905, and the Editor himself on the production and recent developments in the principal copper districts of the United States and foreign countries, the space devoted to this metal covering a total of 78 pages.

The subject of Gold and Silver is edited by Frederick Hobart, of the *Engineering and Mining Journal*. In the 90 pages on the subject are many sections by engineers in the field; among them: Geo. E. Collins, A. Selwyn-Brown, R. N. Bell, W. Fischer Wilkinson (on the Transvaal) and H. C. Hoover (on Western Australia). Alfred James writes on the Progress in Gold-Ore Treatment; J. P. Hutchins, on Gold Dredging (chiefly in foreign countries), giving a review of recent improvements in method and in the design and construction of dredges; Charles H. Fulton, on Cyanidation During 1905, and Robert H. Richards on the Progress in Gold Milling, including Hydraulicking and Gold Dredging in the United States.

W. R. Ingalls devotes 65 pages to the production of Lead and recent developments in its Metallurgy. Mr. Ingalls also contributes important articles on the Tin and Zinc industries. F. H. Hobart reviews the Iron and Steel industry. Progress in Ore-Dressing and Coal Washing, and Improvements in Sampling and Assaying, by H. O. Hofmann, are valua-

ble features of the volume. The work closes with the usual tabulations of the world's mineral and metal production, for the decade ending with 1905.

It may interest the readers of the QUARTERLY to note that the contributors to the volume of the Mineral Industry include eight graduates of the School of Mines, viz: L. S. Austin and C. H. Fulton, whose articles are noted above; Edward K. Judd, who writes on Aluminum, Antimony, Chromium, Corundum, Graphite, Nickel, Cobalt, Sulphur and Pyrites: R. Meeks (tungsten), R. K. Painter (pyrites in Virginia), J. W. Paul (coal and coke in West Virginia), W. B. Phillips (quicksilver in Brewster County, Texas) and H. A. Wheeler (lead in southeastern Missouri).

We think the present issue of this useful publication, which was begun in 1892, is quite up the standard of the previous volumes.

R. P.

Electricity as Applied to Mining. By ARNOLD LUPTON, M.I.C.E., M.I.Mech.E., M.I.E.E., Mining Engineer and Colliery Manager, late Professor of Mining in Yorkshire College; G. D. ASPINALL PARR, M.Sc., M.I.E.E., Assoc. M.I.Mech.E., Head of Elect. Eng. Dept., University of Leeds and HERBERT PERKIN, M.I.M.E., Cert. Colliery Manager and Lecturer in Mining, University of Leeds. Second Edition, Revised and Enlarged. New York, D. Van Nostrand Co.; London, Crosby, Lockwood and Son, 1906. 320 pp., 190 ills. Price, $4.50.

The first ed tion of this work was published in 1903 and reviewed in the *S. of M. Quarterly*, Vol. 24, No. 4, p. 514. In the revision a number of chapters have been altered; some condensed and others extended. Condensation and excision amount to about ten pages and new matter to fifty pages.

In Chapter I., which deals chiefly with various fundamental matters, the subjects of electrical units of current, pressure and resistance, together with primary and secondary cells, have been materially condensed, and we think with advantage, considering the purpose and general scope of the book. Chapter II. has been but little altered, except as to the nature and operation of the "Compound Dynamo." A brief discussion of the principles of the alternating current has been added, however, together with new matter on alternating current motors. New material of value is also given concerning the performance of generators and motors, specially as to speed regulation, starting torque, overload capacity and efficiency. A series of diagrams (pp. 72–73), showing the characteristic curves of the various types of motors, are also useful. To Chapter IV. has been added a short description of the new Curtis steam-turbine, which combines to a certain extent the principles of both the Parsons and DeLaval. In Chapter V. a brief section on the 3-phase, 4-wire system, for running lamps or small motors from a 3-phase system, is inserted, and in Chapter VI. the discussion of motor-starting rheostats, and the starting of shunt and series-wound motors, has been amplified. There is some new matter in Chapter IX., on Riedler pumps, more details as to electrically-driven centrifugal pumps and some additions under the head of electric underground haulage plants.

In Chapter XIII., the subject of Electric Winding (hoisting) has been somewhat expanded, but in view of the increasing importance of the sub-

ject, we think it should have been treated still more fully, with data as to the comparative efficiencies of steam and electric hoisting engines.

A useful addition to the book is the appendix, containing the "Special Rules for the Installation and Use of Electricity, issued by the (British) Home Office under the Coal Mines Regulation Act of 1887," and adopted in 1905.

While this new edition of the book is to be welcomed, there is still room for considerable amplification of the subject matter in certain directions; for example, the installation, operation, efficiencies and costs, of some of the larger and more important applications of electricity to mine service, such as hoisting and pumping; also, the development of water powers, and the design and erection of hydro electric plants.

R. P.

Structural and Field Geology for Students of pure and applied Science. By JAMES GEIKIE, LL.D., Professor of Geology in the University of Edinburgh. New York, D. Van Nostrand Co., 1905. 8vo. xx + 435 pp.; plates 56, figures 142. $4.00.

The work before us is the result of twenty years experience in giving a course specially designed for those who were to use geology in professional life. The original lectures were delivered in the University of Edinburgh, where, as the author tells us, no difficulty has arisen in having in the same class students of both pure and applied science. The same experience, it may be remarked, has been gained at Columbia, and the constant emphasis laid upon the close connection between general science and the practical affairs of life, but serves to give point and interest to the instruction.

The first five chapters of the work are devoted to the rock-forming minerals and the rocks which have resulted from them. They constitute a brief but excellent review of this branch of the subject. The author draws frequently upon the results of microscopic study and freely uses photo-micrographs, perhaps, if anything mentioning more of these minute characters than can be seen by an observer with only a lens.

Chapter VI., briefly discusses fossils not as to kinds, but as to methods of preservation and general significance. There being no treatment of stratigraphical geology, beyond a table of the formations of Great Britain in an Appendix, preparation in this branch of the subject is assumed from other sources.

A number of important structural features next receive attention, such as stratification and the formation of rock-beds; concretionary and secretionary structures; inclination and curvature of strata; joints; faults or dislocations; structures resulting from denudation; eruptive rocks, mode of their occurrence; alteration and metamorphism. These topics are clearly discussed and well illustrated. Indeed some particularly fine pictures are drawn from the stores of the British Geological Survey.

The above topics naturally lead up to ore-formations, to whose description two chapters are devoted. Geological surveying follows, and the preparation of geological maps and sections; then economic aspects of geological structure. The latter topic opens out an interesting field with some striking illustrations and applications. Soils and subsoils, and lastly geological structure and surface features conclude the book proper — but

in five brief appendices are given a number of matters, valuable for reference.

The work is written in a delightful and clear literary style and holds the reader's interest from the start. One feels that references to original sources might have been sometimes given with profit, for none whatever appear under any of the topics, and a reader might often wish to go more deeply into a special theme. But as the work is more particularly designed as an introduction to field work and interpretation, these considerations probably did not strongly appeal to the author.

J. F. K.

Clays, their Occurrence, Properties and Uses, with especial reference to those of the United States. By HEINRICH RIES, Ph.D. New York, John Wiley & Sons, 1906. 8vo, xvi + 490 pages; 65 figures, 44 plates. Cloth, $5.00.

The author of the above work, now Professor of Economic Geology in Cornell University, took his first degree in the School of Mines, 1892, in the course in geology aud palæontology, which formerly ran parallel with that of mining engineering. For his graduatian thesis he was assigned the "Clays of the Hudson Valley." These invaluable resources of New York had up to that time received almost no special study and were regarded as geological problems of slight interest. The thesis brought out the fact, however, that they were the most valuable single mineral asset which the State possessed and abundantly deserved the further investigation which, after graduating, Mr. Ries bestowed upon them with the support of the State Geologist. Beginning thus the special investigation of clays in his undergraduate years, Mr. Ries has continued it with marked efficiency and success up to the present. He began when interest generally was just awakening in these materials and he has been one of the two or three Americans, foremost in the authoritative discussion of them. The work before us is the fruition and summary of years of experience, investigation and travel, in part supported by the Barnard Fellowship; of reports for the States of New York, New Jersey, Maryland, North Carolina, Alabama, Michigan, Wisconsin and Texas; and of many papers for the United States Geological Survey. Obviously the author's preparation and qualifications for the work were altogether exceptional.

The book opens with a discussion of the origin of clay. The various processes are passed in review, with their results in the several kinds. The schemes of classification and the changes after formation follow. The chemical properties next receive attention, including the mineralogy of clays; the methods of analysis; the chemical composition; and effects of various ingredients upon the products of manufacture. The physical properties are taken up with a very interesting discussion of the puzzling question of plasticity; of the methods of testing clays; of shrinkage in firing; of fusibility and of some minor phenomena. The kinds of clays and their applications are treated at length, and finally as the last chapter of the general and introductory part, the methods of mining and manufacture. This portion occupies 275 pages, somewhat more than one half the total.

The latter partion is occupied with the description of the productive regions, by states in alphabetical order. The clays under each are ttreated

by geological horizons from oldest to latest. Copious analyses are cited and the bibliography is full and conveniently placed. Maps and illustrations excellently executed are richly employed and add much to the interest of the work.

The book cannot fail to meet a warm welcome among those engaged in the industries based on clay, and to be of great service to both mannfacurers and students. J. F. K.

A Treatise on Rocks, Rock-weathering and Soils. By GEORGE P. MERRILL. 8vo, pp. xxi, 400, plates 31, figures 42. Price $6.00 net. The Macmillan Co., New York. 2d edition, 1906.

All geologists interested in the process of weathering in rocks with the attendant production of surface deposits and all agriculturalists who desire to follow up the derivation of the soils which they cultivate will welcome the appearance of this new edition of a standard work. Nine years ago the first issue appeared and immediately gained its place as a text-book of petrology, written from a new point of view. In the usual treatment of the general subject of rocks and especially for purposes of instruction, fresh, and, so far as possible, unaltered specimens are assumed. This is necessary since only thus can sharpness and accuracy in establishing species be gained. It is also necessary as a starting point for a work like Dr. Merrill's and thus we find that somewhat more than the first third of the book is a brief text-book upon rocks and of the usual type. The second third treats of the processes of weathering both chemical and physical. The various agents of chemical change are set forth and in particular, their effects upon different kinds of rocks. The physical manifestations and their relations to texture and other effects are reviewed from all important points of view.

After a few pages devoted to the transportation and redeposition of rock debris, the concluding pages, almost a third of the book, treat of the "Regolith," Dr. Merrill's word for the outer blanket of loose or unconsolidated materials which covers the solid and unaltered rock beneath. Sedentary deposits, transported deposits and the soil itself are successively passed in review.

Altogether the author presents a work that is thorough, scholarly and philosophical. It is written in a clear and flowing style and will more than maintain the enviable position gained by the first edition.

J. F. K.

Geology of Western Ore Deposits. By ARTHUR LAKE. New edition, rewritten and enlarged. Pp. 438, numerous figures. Kendrick Book and Stationery Co., Denver.

Somewhat over ten years ago the first edition of the above work was issued and since then it has been widely read especially in the West. The development of new districts and the need of bringing matters up to date have led to the preparation of a revised issue. The book opens with nine chapters devoted to the general principles and phenomena of geology and mineralogy which bear on the deposition of ores. Two chapters are devoted to placers and then eleven to mining districts in Colorado. One chapter contains a review of all the other western states, Alaska and British Columbia; one treats of tin in Alaska and one contains conclud-

ing remarks. There is a glossary and an appendix with a few rather rough cuts of index fossils. The book contains much of interest and importance to those engaged in mining or connected with the industry, but the matter greatly needs digestion, logical arrangement and the proper distribution of emphasis. There is no table of contents and no list of figures and plates. The plates of fossils at the back are evidently taken bodily from some other work, since although but seven in all, they bear numbers irregularly distributed from 17 to 62. Greater care in editing is also needed in a few other instances.

J. F. K.

The School of Mines Quarterly.

Journal of Applied Science

VOL. XXXVIII., 1906-7.

NEW YORK CITY.

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CONTENTS:

North American Index Fossils. II. (concluded) By A. W. Grabau and H. W. Shimer 251
Principle and Operation of the Féry Radiation Pyrometer. By C. H. Wilson and F. Maeulen 353
Influence Lines for Suspended Cantilevers. By Myron S. Falk 362
Notes on Three-Phase Traction. By Gerard B. Werner 376
Supplies for Engineering Trips. By William Newbrough 387
Abstracts of Recent Mining Decisions. By J. W. Thompson 389
Metallurgical Abstracts. By William Campbell 392
Alumni and University News 407
Book Reviews 409

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VOL. XXVIII. APRIL, 1907. No. 3.

NORTH AMERICAN INDEX FOSSILS. II.
CONCLUDED.

BY A. W. GRABAU AND H. W. SHIMER.*

LV. DALMANELLA Hall and Clarke.

Plano-convex or subequally biconvex, subcircular in outline. Pedicle valve elevated and arched over the cardinal area. Surface covered with fine, rounded, bifurcating striæ which curve very conspicuously from the umbo to the sides of the valve. Teeth prominent. Ordovicic–Devonic.

A. Radiating striæ prominent and coarse ..... 188. *D. testudinaria.*
B. Radiating striæ very fine ..... *.
* Shell small (less than ¾ inch wide) ..... 1.
1. Pedicle valve wider than long ..... *a.*
a. Shell thin ..... 189. *D. emacerata.*
a. Shell convex ..... 190. *D. subæquata.*
1. Pedicle valve longer than wide ..... 191. *D. elegantula.*
* Shell more than ¾ inch wide ..... 2.
2. Brachial valve slightly convex and with broad mesial depression. 193. *D. subcarinata.*
2. Brachial valve strongly convex and with slight mesial depression. 192. *D. perelegans.*

188. **D. testudinaria** (Dalman). (Fig. 311, *a–e.*) Ordovicic.

Pedicle valve convex at umbo, rapidly decreasing in height before the edge of the shell is reached; cardinal area high; umbo but slightly incurved. Brachial valve very slightly convex or depressed. Surface marked with very prominent radiating striæ crossed by faint concentric lines.

Chazy–Lorraine throughout America.

* Copyrighted 1907 by A. W. Grabau & H. W Shime

189. **D. emacerata** Hall. (Fig. 311, *i–m.*) Ordovicic.

Distinguished by its thinness, the brachial valve being flat and the pedicle valve depressed convex. Cardinal area almost linear. Surface finely striated.

Utica of Ohio, Missouri, Minnesota and Quebec.

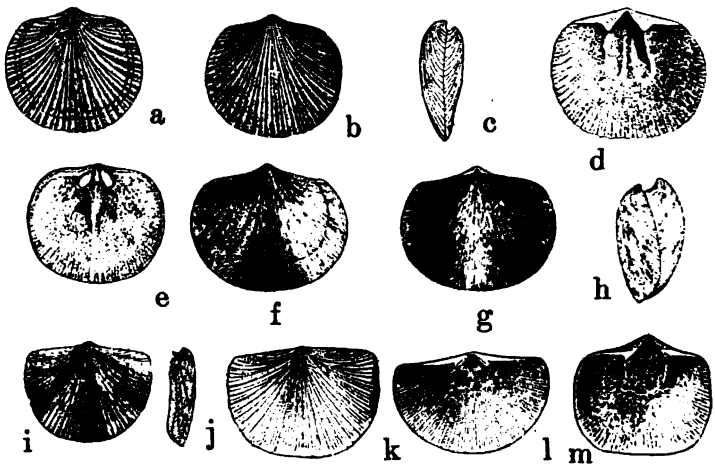


FIG. 311. *a–e, Dalmanella testudinaria; f–h, D. subæquata; i–m, D. emacerata.* (Minnesota Geol. Surv.)

190. **D. subæquata** (Conrad). (Fig. 311, *f–h.*) Ordovicic.

Both valves convex, the pedicle valve more than the brachial especially at the umbo. Surface marked with fine radiating striæ which are perforate at intervals.

Trenton of Missouri, Wisconsin, Minnesota, Iowa, Quebec.

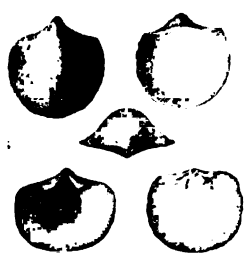


FIG. 312. *Dalmanella elegantula.* (After Hall.)

191. **D. elegantula** (Dalman). (Fig. 312.) Siluric.

Pedicle valve very strongly convex with a high, narrow cardinal area. Brachial valve nearly flat and marked with an undefined median sinus. Striæ fine and close set.

Clinton and Niagara; widely distributed throughout eastern North America.

192. **D. perelegans** Hall. (Fig. 313.) Devonic.

Pedicle valve convex but not subcarinate as in *D. subcarinata.*

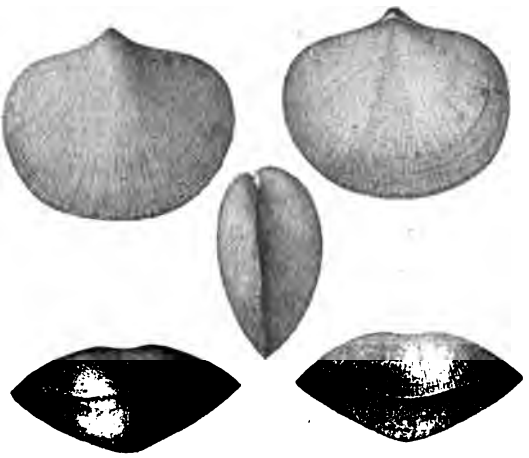


FIG. 313. *Dalmanella perelegans.* (After Hall.)

Brachial valve very convex and only slightly depressed medially. In other respects very like *D. subcarinata.*

Helderbergian of New York and Tennessee.

193. **D. subcarinata** Hall. (Fig. 314.) Devonic.

Pedicle valve very convex, subcarinate along median line; umbo strongly incurved over the cardinal area. Brachial valve slightly convex near the hinge with an undefined depression along the

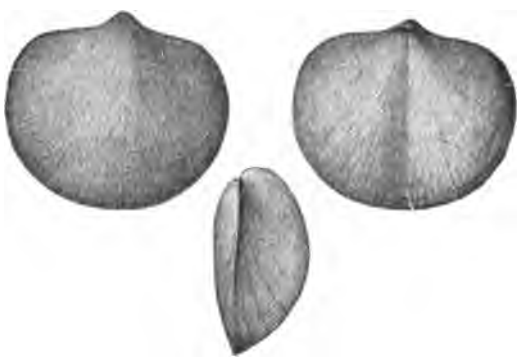


FIG. 314. *Dalmanella subcarinata.* (After Hall.)

median line which broadens rapidly anteriorly. Striæ very fine, numerous and irregularly bifurcating.

Helderbergian of New York, Tennessee, Missouri, Wisconsin, Nova Scotia.

LVI. RHIPIDOMELLA Oehlert.

Shell almost circular. Both valves gently convex. Hinge line short. Slight median depression present in each valve. Surface covered with fine, hollow striæ, often opening on the surface. From the base of the two strong teeth on the interior of the pedicle valve a curving ridge extends forward and borders the large flabelliform muscular scars which extend one third or more the length of the valve and are deeply impressed. Shell structure punctate. Siluric–Carbonic.

A. Rounded posteriorly, *i. e.*, beak but slightly elevated above hinge line..... *.
* Large (average width over ½ inch) ..... 1.
1. With broad medial depression in pedicle valve ..... *a*.
a. Outline usually transversely oval..... 1′.
1′. Posterior border curved..... 195. *R. oblata*.
1′. Posterior border straight..... 196. *R. alsa*.
a. Outline circular..... 198. *R. vanuxemi*.
1. Without broad depression in pedicle valve..... *b*.
b. Beaks prominent..... 197. *R. livia*.
b. Beaks not prominent..... 2′.
2′. Radiating striæ indistinct..... 202. *R. michelini*.
2′. Radiating striæ strong..... 200. *R. penelope*.
* Small (width not exceeding ½ inch)..... 2.
2. Sinus present in both valves..... 201. *R. thiemei*.
2. Sinus absent in pedicle valve..... 205. *R. pecosi*.
B. Pointed posteriorly, *i. e.*, with somewhat elevated beak..... **.
** Small (width not exceeding ⅔ inch)..... 3.
3. With slight mesial depression. Beak not incurved..... 194. *R. hybrida*.
3. With strong mesial sinus. Beak of pedicle valve somewhat incurved. 204. *R. dubia*.
** Of medium size (not below ⅔ inch in width)..... 4.
4. Curved posteriorly..... 199. *R. leucosia*.
4. Straight posteriorly..... 203. *R. burlingtonensis*.

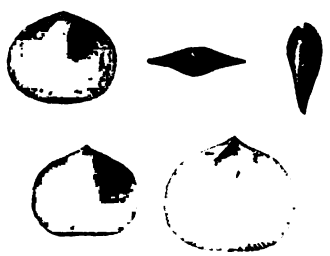


FIG. 315. *Rhipidomella hybrida*. (After Hall.)

194. **R. hybrida** (Sowerby). (Fig. 315.) Siluric.

Width exceeding length. Valves very nearly equal. Beaks scarcely incurved. Pedicle valve marked with a broad, undefined depression.

Niagaran of New York, Kentucky, Tennessee, Ohio, Indiana, Missouri, Nova Scotia.

195. **R. oblata** Hall. (Fig. 316–317.) Devonic.

Large, transversely oval. Pedicle valve convex at beak and concave toward the front. Brachial valve very convex. Beaks of both valves of slight and nearly equal elevation. Surface faintly striated.

Helderbergian of New York, etc.

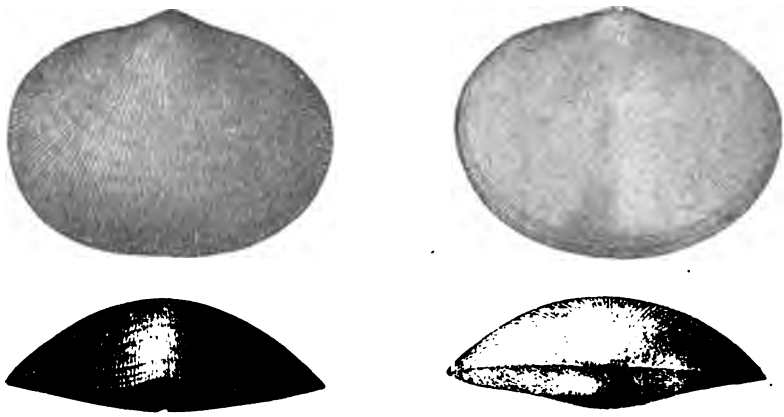


FIG. 316. *Rhipidomella oblata.* (After Hall.)

FIG. 317. *Rhipidomella oblata* internal molds. (After Hall.)

196. **R. alsa** Hall. (Fig. 318.) Devonic.

Large, nearly transversely oval but hinge line somewhat extended, producing for some distance a straight posterior border.

FIG. 318. *Rhipidomella alsa* and internal molds. (After Hall.)

Pedicle valve depressed convex, becoming nearly flat. Brachial valve convex and marked by a mesial sinus. Differs from *R. oblata* in the absence of the depression in the pedicle valve, in the more extended hinge line and in the presence of a sinus in the brachial valve.

Schoharie of New York, Michigan, etc.

197. **R. livia** (Billings). (Fig. 319, *a–b.*) Devonic.

Differs from *R. vanuxemi* in the lesser convexity of the brachial valve and in the absence of a mesial sinus, while the beak is shorter,

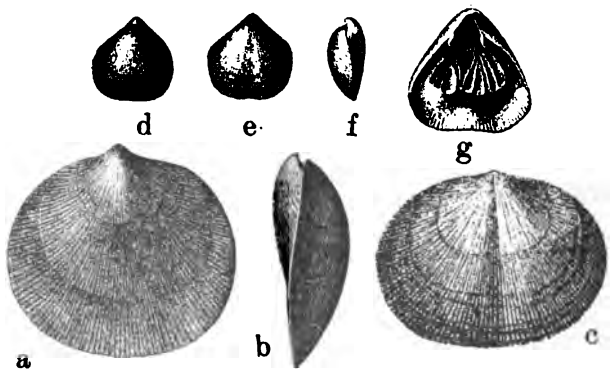


FIG. 319. *a–b, Rhipidomella livia, c, R. michelini* (after Hall); *d–g, R. dubia.* (After Whitfield.)

not rising to nearly the same height as in the pedicle valve. Its suborbicular form distinguishes it from *R. leucosia.*

Onondaga of New York, Ohio, Ontario, Quebec.

198. **R. vanuxemi** Hall. (Fig. 320, *a–c.*) Devonic.

Subcircular. Pedicle valve nearly flat, becoming moderately convex near the beak. Brachial valve convex.

Onondaga–Hamilton of New York, Ohio, Michigan, Illinois, Iowa, Ontario.

199. **R. leucosia** Hall. (Fig. 320, *d–e.*) Devonic.

Broadly ovate with pointed beak. Both pedicle and brachial valves convex.

Hamilton of New York, Maryland.

200. **R. penelope** Hall. (Fig. 320, *f–g.*) Devonic.

Large, subcircular. Brachial valve regularly convex and slightly depressed medially. Pedicle valve depressed convex above, be-

coming flat or concave toward the margin but lacking a sinuosity in front. Beaks not prominent.

Hamilton of New York.

201. **R. thiemei** (White). Devonic and Mississippic.

Usually a little wider than long. Convex at beak but flattened toward the front owing to a broad, faint sinus in each valve. Beak of pedicle valve short, elevated and slightly incurved beyond the

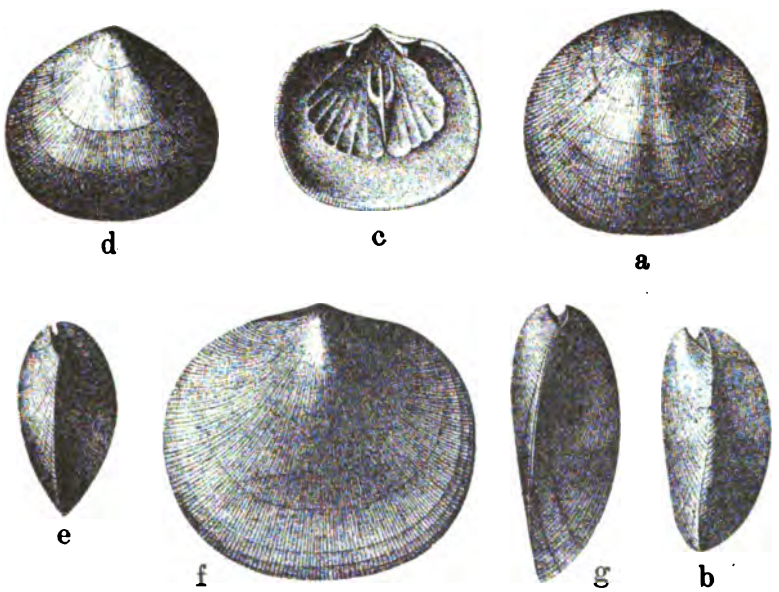


FIG. 320. *a–c, Rhipidomella vanuxemi; d–e, R. leucosia; f–g, R. penelope.* (After Hall.)

cardinal area. Brachial valve the deeper. Differs from *R. vanuxemi* in its smaller size, greater gibbosity and in the more elevated and incurved beak of the pedicle valve.

Chemung of New York and Kinderhook of Iowa.

202. **R. michelini** (L'Eveillé). (Fig. 319, *c.*) Mississippic.

Quite similar to *R. vanuxemi* but differs in the parallel direction of the dental lamellæ and in the character of the radial striæ.

Waverly of Pennsylvania, Ohio, Kentucky, New Mexico.

203. **R. burlingtonensis** Hall. Mississippic.

Of medium size, subcircular. Valves subequally convex. Beak of pedicle valve extended and cardinal area high.

Burlington of Illinois, Iowa, Missouri.

204. **R. dubia** Hall. (Fig. 319, *d–g.*) Mississippic.

Distinguished by its small size, nearly equal convexity of the two valves, the prominent beak of the pedicle valve and the distinctly defined sinus of the pedicle valve.

St. Louis of Kentucky, Indiana, Illinois, Missouri, Iowa.

205. **R. pecosi** (Marcou). (Fig. 321, *a–c.*) Carbonic.

Small. Length at times exceeding breadth. Pedicle valve often flattened toward the front and lacking a definite mesial sinus. Brachial valve more convex than the pedicle valve. Radiating striæ crossed by fine concentric growth lines and near the front by imbricating lines.

Throughout the Carbonic of North America.

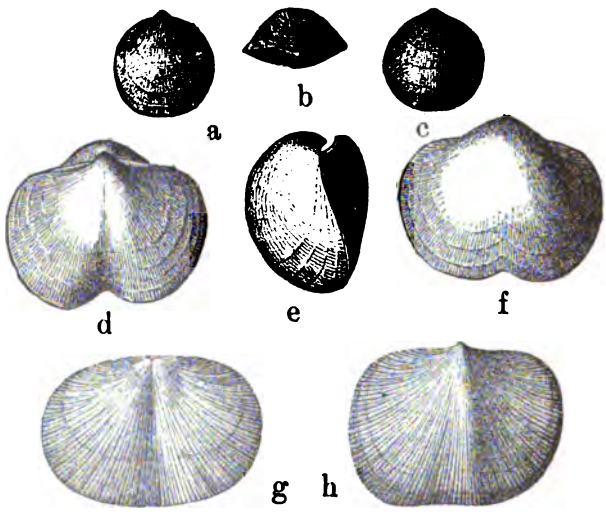


FIG. 321. *a–c, Rhipidomella pecosi; d–f, Schizophoria striatula* (Ind. Geol. Surv.) *g–h, S. tioga.* (After Hall.)

LVII. SCHIZOPHORIA King.

Pedicle valve depressed convex, becoming slightly concave toward the front. Brachial valve very convex. Hinge line short. Cardinal areas moderately high. Plications rounded, hollow and exceedingly fine. Muscular area of pedicle valve has elevated margins and is deeply sunk in the substance of the shell. Shell substance very punctate. This genus differs from Hebertella principally in its much shorter hinge line and its punctate shell. Siluric–Carbonic.

A. Length exceeding breadth..... 210. *S. macfarlani.*
B. Breadth exceeding length..... *.
* Striæ fasciculate, *i. e.*, in bundles.....211. *S. tioga.*
* Striæ not fasciculate ..... 1.
1. Hinge line quite long, forming nearly the greatest width of shell. Shell large, often exceeding 1 inch in width..... 212. *S. swallovi.*
1. Hinge line equalling only about half the width of the shell..... *a.*
a. Beak of pedicle valve prominent and pointed..... 1′.
1′. Beak of brachial valve not strongly arched, vascular impressions not bifurcating but diverging..... 206. *S. multistriata.*
1′. Beak of brachial valve strongly arched, vascular impressions not bifurcating, but parallel or converging..... 208. *S. tulliensis;*
1′. Beak of brachial valve arched, vascular impressions bifurcating. 207. *S. propinqua.*
a. Beaks of both valves about equal and not pointed..... 2′.
2′. Cardinal areas narrow..... 213. *S. resupinoides.*
2′. Cardinal areas moderately high .....209. *S. striatula.*

206. **S. multistriata** Hall. (Fig. 322.) Lower Devonic.

Of medium size. Pedicle valve with broad, undefined sinus and prominent, slightly incurved beak. Brachial valve with obtuse beak. Hinge line forming about half the width of the shell. Surface marked by fine, equal, radiating striæ. Concentric growth lines very faint. Vascular impressions slightly diverging forward but not bifurcating.

Helderbergian of New York.

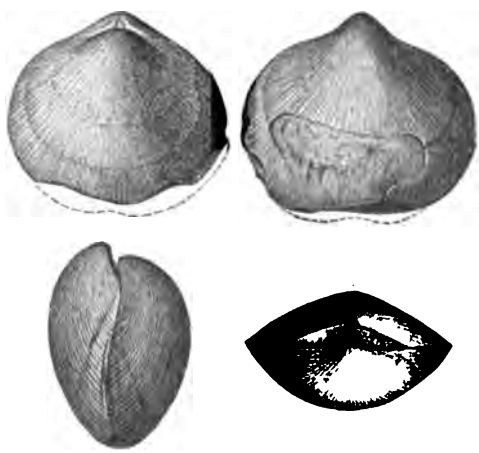


FIG. 322. *Schizophoria multistriata.* (After Hall.)

207. **S. propinqua** Hall. Middle Devonic.

Brachial valve somewhat more gibbous than in *S. multistriata*, and pedicle beak and area generally somewhat more arcuate. Vascular impressions on interior of valves bifurcating from one to three times before reaching front of shell.

Onondaga of New York, Ohio, etc.

208. **S. tulliensis** Hall. Upper Devonic.

Differs from *S. propinqua* and *S. multistriata* in being more gibbous with the beak of the brachial valve more elevated and

arching, and in having the divisions of the vascular impressions running nearly parallel to each other or slightly converging, without bifurcation.

Tully of New York, and equivalent horizons of Nevada, etc.

209. **S. striatula** (Schlotheim). (Fig. 321, *d–f.*) Middle and Upper Devonic.

Brachial valve sinuate in front. Pedicle valve with a broad, undefined sinus, sometimes incurving the margin of the shell. Surface very finely and evenly striated.

Widely distributed throughout North America.

210. **S. macfarlani** (Meek). Middle and Upper Devonic.

Very gibbous. Length in adults slightly greater than the breadth which is about 1" inch. Cardinal and umbonal regions narrow. Hinge line scarcely equalling half the greatest width of the shell. Pedicle valve depressed convex, bearing a broad sinus anteriorly; cardinal area of moderate height. Brachial valve very gibbous with a greatly incurved umbo. About ten fine, bifurcating, radiating striæ may be counted in the space of $\frac{1}{10}$ inch.

New York, Iowa, Nevada, Northwest Territory.

211. **S. tioga** Hall. (Fig. 321, *g–h.*) Devonic.

Differs from *S. striatula* in its smaller size, usually more pronounced elevation of the pedicle valve and in the angular, fasciculate striæ.

Portage and Chemung of New York, Ohio.

212. **S. swallovi** Hall. (Fig. 323.) Mississippic.

Large. Hinge line less than the width of the shell below. Pedicle valve depressed convex near the beak and flat at sides with

FIG. 323. *Schizophoria swallovi*, ×⅔. (After Hall.)

a broad depression extending from the middle to the front. Brachial valve gibbous. Surface covered with fine and close radiating striæ and sharp concentric growth lines.

Burlington of Illinois, Iowa and Missouri.

213. **S. resupinoides** (Cox). Carbonic.

Transversely ovate to subquadrate. Hinge line forming about half the greatest width of the shell. Cardinal areas narrow, that of the brachial valve being the higher.

Kentucky, Arkansas, New Mexico.

LVIII. ENTELETES Fischer de Waldheim.

Subglobular, plicate; brachial valve the more convex. Hinge line short. Cardinal area of pedicle valve high; that of brachial valve low, at times linear. Cardinal process small, erect and multi-lobate. Between the much extended and parallel dental

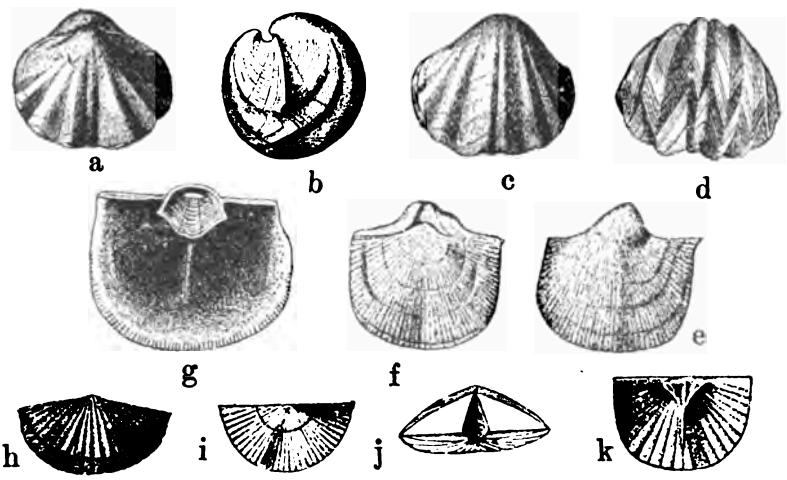


FIG. 324. *a–d*, *Enteletes hemiplicata* (Ind. Surv.); *e–g*, *Clitambonites diversus*, ventral and dorsal views and interior of brachial valve (enlarged); *h–k*, *Scenidium anthonense*, ventral, dorsal and cardinal views and interior of brachial valve (Min. Surv.).

lamellæ is a blade-like median septum extending from beneath the beak and enlarging to the middle of the valve where it suddenly terminates. Crural plates of brachial valve support long, curved crura. Entire surface of shell, including the few more or less strong plications, covered with fine radiating striæ. Upper Carbonic.

214. **E. hemiplicata** Hall. (Fig. 324, *a–d.*) Upper Carbonic.

Surface covered with fine and crowded radiating striæ and a few large and subangular radial plications which are distinct anteriorly

and die out towards the umbo. They are crossed near the front by a few concentric lines of growth.

Missouri, Illinois, Iowa, Nebraska, Colorado.

LIX. Clitambonites Pander.

Semicircular. Hinge line straight, forming greatest diameter of shell. Pedicle valve convex or subpyramidal; cardinal area high and usually vertical with a broad convex deltidium perforate at apex; on the interior the dental plates unite to form a spondylium which is supported on a median septum. Brachial valve depressed convex or flattened. Upper Cambric–Ordovicic.

215. **C. diversus** (Shaler). (Fig. 324, *e–g.*) Ordovicic.

Subquadrangular. Umbo of pedicle valve always laterally inclined toward either extremity of the hinge line. Surface marked by numerous prominent striæ crossed by delicate crowded growth lines.

Trenton–Lorraine of Wisconsin, Minnesota, Ontario, Manitoba, Anticosti.

LX. Scenidium Hall.

Small. Hinge line straight, usually equalling the greatest width of the shell; delthyrium in each valve. Pedicle valve subpyramidal with a high and usually erect cardinal area. Brachial valve depressed, convex to concave, with low cardinal area. The small cardinal process extends forward as a median septum through the length of the valve and is at times so developed anteriorly as to reach into the pedicle valve. Ordovicic–Devonic.

216. **S. anthonense** Sardeson. (Fig. 324, *h–k.*) Ordovicic.

Small with extended hinge line and conspicuous mesial sinus and fold. Surface radiately striated.

Trenton of Tennessee, Illinois, Minnesota.

LXI. Syntrophia Hall and Clarke.

Transversely elongate, biconvex. Hinge line nearly equalling the greatest width of shell. Cardinal area long and straight; an open delthyrium on each valve. Spondylium deep and short, its anterior half unsupported. Upper Cambric–Ordovicic.

217. **S. calcifera** (Billings). (Fig. 325.) Upper Cambric.

Brachial valve triangular posteriorly. Moderate sinus in pedicle valve and fold on brachial. Surface marked by concentric growth lines only. Average length about 3/8 inch.

Saratogan, etc., of Missouri, Utah, Nevada, Quebec, Newfoundland.

FIG. 325. *Syntrophia calcifera*, pedicle and brachial valves. (After Walcott.)

LXII. CAMARELLA Billings.

Small, smooth in the umbonal region with a few low plications anteriorly; no cardinal areas. Pedicle valve with erect beak and an open delthyrium. Well-defined spondylium present. Brachial valve at maturity the more convex. Median sinus on pedicle valve and fold on brachial. Ordovicic–Siluric.

218. **C. varians** Billings. (Fig. 326.) Ordovicic.

FIG. 326. *Camarella varians* (Canadian Surv.).

Subtriangular. Valves moderately and equally convex. Anterior angles rounded. Plications rounded, 6–8, of which 2–4 occupy the mesial sinus and 3–5 the fold. Length about 1/3 inch, width about the same.

Beekmantown–Chazy of New York, Newfoundland, Mingan Islands.

LXIII. PARASTROPHIA Hall and Clarke.

Subcircular. Hinge line moderately long and straight. No cardinal areas. Brachial valve the larger and more convex, its beak projecting conspicuously beyond that of the pedicle valve. Otherwise much like *Camarella*. Ordovicic–Siluric.

219. **P. hemiplicata** Hall. (Fig. 327.) Ordovicic.

Subglobose, wider than long with thickness often equal to length. Hinge line short. Pedicle valve depressed convex with an abrupt broad sinus. Brachial valve very convex with a broad median fold. Surface marked by about 6–8 plications, strong toward the front but fading away entirely toward the umbo. 2–3 plications occupy the sinus and 3–4 the fold; all are crossed by concentric lines.

Trenton of New York, Pennsylvania, Wisconsin, Minnesota, Ontario, Manitoba.

LXIV. ANASTROPHIA Hall.

Differs externally from *Parastrophia* in having a more prominent umbo in the brachial valve and in that the valves are covered with many sharp plications extending to the beaks. Siluric–Devonic.

FIG. 327. *Parastrophia hemiplicata* (Canadian Geol. Surv.).

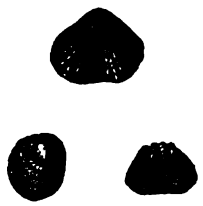


FIG. 328. *Anastrophia interplicata* (N. Y. State Surv.).

220. **A. interplicata** Hall. (Fig. 328.) Siluric.

Subovate. Brachial valve much more convex than the pedicle. Beaks very short and closely incurved. Plications three or four on each side of the beak near the cardinal margins; an additional one is inserted between each pair, except the central ones, about half way toward the front.

Niagaran of New York, Kentucky and Wisconsin.

221. **A. internascens** Hall. (Fig. 329.) Siluric.

Ovoid or subglobose with brachial valve slightly the more gibbous. Pedicle valve with depressed anterior portion marked by

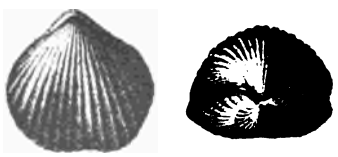


FIG. 329. *Anastrophia internascens.* (After Hall.)

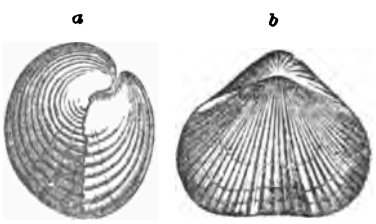


FIG. 330. *Anastrophia verneuili* (Canadian Geol. Surv.).

a broad, undefined sinus and short beak closely incurved over umbo of opposite valve. Brachial valve elevated in center, sometimes forming a broad undefined fold.

Niagaran of Kentucky, Indiana, Wisconsin.

222. **A. verneuili** (Hall). (Fig. 330.) Devonic.

Globose with width generally exceeding length. Pedicle valve with distinct sinus. Brachial valve very elevated with exceedingly gibbous beak, strongly incurved and covering the foramen of the opposite valve.

Helderbergian of New York, Tennessee, Greenland.

LXV. Conchidium Linnæus.

Elongate subpentagonal, strongly inequivalved, biconvex, without well defined median sinus and fold. Pedicle valve highly arched; delthyrium very broad. Spondylium narrow and deep,

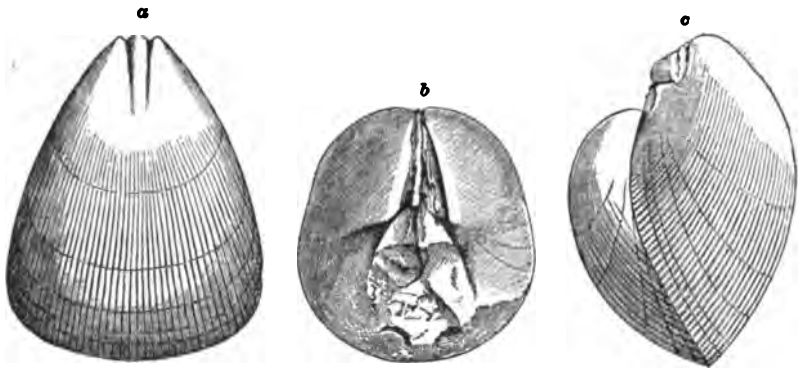


Fig. 331. *Conchidium occidentale* (Canadian Geol. Surv.).

supported by a high septum. Beak of brachial valve closely incurved; cardinal process small; a pair of median septa in posterior portion of valve. Surface with numerous radiating plications. Siluric–Devonic.

223. **C. occidentale** Hall. (Fig. 331.) Siluric.

Ovoid. Plications scarcely equal in width to the spaces between them.

Guelph of Wisconsin, Ontario.

224. **C. nettelrothi** Hall & Clarke. (*C. knighti* Nettelroth.) (Fig. 332.) Siluric.

Differs from the preceding in its proportionately greater convexity of valves, narrower form higher pedicle valve, with strongly incurved umbo and pronounced flattenings on either side of the delthyrium, and in the coarser close and sparse plications which extend to the beaks.

Niagaran? of Falls of Ohio Region. Upper Siluric of Nova Scotia.

225. **C. laqueatum** Conrad. Siluric.

Large, trigonal or trapezoidal and very ventricose; pedicle valve twice as long as deep, with scarcely incurved but projecting beak; brachial valve shallower. Plications rounded to subangular, more widely spaced towards lateral margins where they disappear.

Niagaran of Indiana, common.

FIG. 332. *Conchidium nettelrothi.* (After Nettelroth.)

LXVI. STRICKLANDINIA Billings.

Usually large. Valves nearly equal. Pedicle valve with a short median septum in the interior supporting a small and short spondylium. Hinge line straight, cardinal area present on each valve and beak of pedicle valve not highly arched; otherwise very similar to *Conchidium* Siluric.

226. **S. davidsoni** Billings. Siluric.

Longitudinally ovate, $\frac{3}{4}$ inch–3 inches long with width about $\frac{1}{5}$ less. Front of shell narrowed to a linguiform extension. Beaks

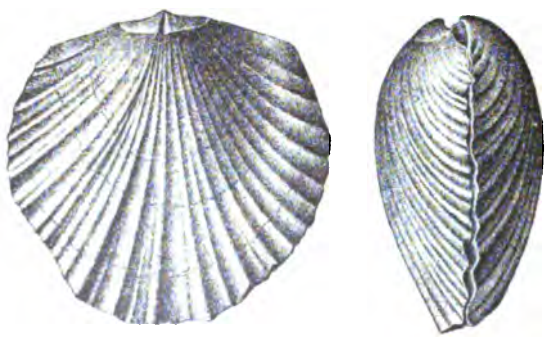


FIG. 333. *Stricklandinia castellana.* (After Hall and Clarke.)

only slightly developed. Pedicle valve often with a faint median sinus in youth, becoming obsolete with age, often developing into a fold. Brachial valve with a fold widening into the linguiform ex-

tension. Surface covered with faint radiating ribs, 3–5 occupying the width of $\frac{1}{4}$ inch at the margin.

Anticosti group of Georgia, and of Anticosti and eastern Canada.

227. **S. castellana** White. (Fig. 333.) Siluric.

Valves nearly equiconvex, subcircular; surface of each valve with strong, irregularly fasciculate or duplicate plications.

Niagaran of Iowa.

LXVII. PENTAMERUS Sowerby.

Strongly inequivalved, biconvex with highly arched pedicle valve. Like *Conchidium*, but with surface smooth or with but a few broad, obscure, radiating undulations. Siluric.

228. **P. oblongus** Sowerby. (Fig. 334.) Siluric.

Very large, varying in outline with age. Wider anteriorly. Valves strongly convex at beaks. Surface marked only by concentric lines of growth which are strongest in old shells. The pair

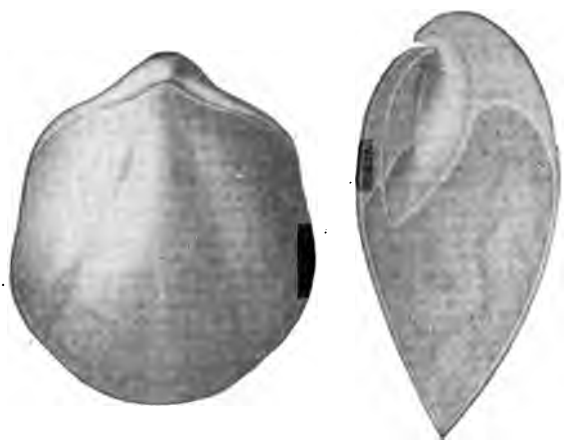


FIG. 334. *Pentamerus oblongus*, dorsal and internal views (Pal. N. Y.).

of septa in the brachial valve are near together and subparallel.

Clinton and Niagaran of New York, Kentucky, Ohio, Indiana, Illinois, Iowa, Wisconsin, Ontario, Anticosti.

228*a*. **P. oblongus** var. **subrectus** Hall. Siluric.

Elongate subquadrate outline; high, subrectangular cardinal extremities. Each valve with impressed longitudinal median and

two divergent grooves, which divide again. Sometimes indication of few coarse plicæ.

Niagaran beds of Iowa.

228*b*. **P. oblongus** var. **cylindricus** Hall & Whitfield. Siluric.

Elongate, subcircular in cross-section. Valves more or less distinctly trilobed in anterior half, rounded or truncate in front, generally with shallow sinus in each valve in front. Beak of more convex (pedicle) valve overarching.

Niagaran near Louisville, Kentucky, Wisconsin and Indiana.

LXVIII. Clorinda Barrande.

Small, pentameroid. Median sinus in pedicle valve and fold in brachial. Surface smooth or rarely plicate. Spondylium without a supporting septum. Siluric.

Fig. 335. *Clorinda fornicata* (Pal. Y. N.).

229. **C. (Barrandella) fornicata** (Hall). (Fig. 335.) Siluric.

Pedicle valve very convex with overarching beak. Surface obscurely plicate longitudinally. Umbo of pedicle valve much more gibbous than in *C. ventricosa.*

Clinton and Niagara of New York, Indiana, Wisconsin.

230. **C. (Barrandella) ventricosa** (Hall). (Fig. 336, *a–b*). Siluric.

Small, subglobose, usually wider than long. Both valves strongly ventricose with incurved beaks, that of the pedicle valve being

Fig. 336. *a–b*, *Clorinda ventricosa.* (After Nettelroth.) *c*, *Gypidula comis.* (After Walcott.)

much the higher. Surface more or less marked by concentric lines of growth.

Niagaran of Kentucky, Ohio, Illinois, Wisconsin.

LXIX. PENTAMERELLA Hall.

Pentameroid, more or less rotund, with a sinus on pedicle valve and fold on brachial. Much like *Clorinda* but larger and strongly plicate with a narrow cardinal area. Brachial valve with the crural plates supporting septa conjoined so as to form a broadly sessile spondylium. ? Siluric–Devonic.

231. **P. arata** (Conrad). (Fig. 337.) Devonic.

Ovate, with gibbous pedicle valve which in old age becomes very arcuate with strongly incurved beak. Brachial valve only moder-

FIG. 337. *Pentamerella arata*, average sized, and extremely old age individuals (Pal. N. Y.).

ately convex. Surface covered with angular plications, often developed only below the first third of the length and usually bifurcating.

Schoharie and Onondaga of New York, Ohio, Kentucky, Indiana, Ontario.

232. **P. pavilionensis** Hall. Devonic.

Differs from the preceding, in having the valves more nearly equally convex, and fewer rounded plications which become obsolete toward the beak and often on lateral slopes; and in a well defined fold and sinus with four and three (or two) plications respectively.

Hamilton beds of New York, Falls Ohio, Michigan, etc.

LXX. Gypidula Hall.

Pentameroid, ventricose. Pedicle valve much the larger, with or without a mesial fold; cardinal area generally well defined, cross striated; spondylium unsupported for most of its length. Brachial valve with or without mesial sinus; spondylium large, sessile, acute anteriorly. Siluric–Devonic.

233. **G. (Sieberella) galeata** (Dalman). (Fig. 338.)
Siluric? and Devonic.

Subglobose. Pedicle valve gibbous with a mesial fold toward the front and a strongly incurved beak. Brachial valve gibbous above, with or without a mesial sinus near the margin. Surface in youth smooth but developing longitudinal plications in older forms

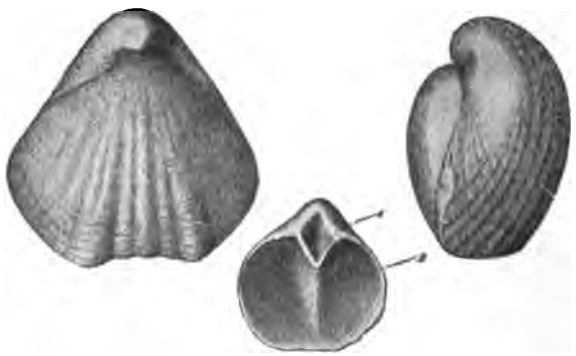


Fig. 338. *Gypidula galeata* (Pal. N. Y.).

Differs from *G. comis* in its greater gibbosity, in the absence of a distinct cardinal area, in the greater prominence of the plications and in the greater incurving of the beak of the brachial valve under that of the pedicle valve, thus concealing the delthyrium.

Helderbergian (Coeymans) of New York, Pennsylvania, Maryland, New Brunswick, Northwest Territory. ? Niagaran of Indiana. Middle Devonic of Europe.

234. **G. (Sieberella) pseudogaleata** (Hall). (Fig. 339.)
Lower Devonic.

Like *G. galeata* but differs in the absence of radiating plications. Becraft of New York, etc.

235. **G. comis** (Owen). (Fig. 336, *c*.) Middle Devonic.

Pedicle valve arcuate with extended and strongly incurved beak; delthyrium large and bordered by a distinct area. Surface ele-

vated into a more or less distinct mesial fold. Brachial valve depressed anteriorly into a sinus. Surface usually bearing below a few rounded plications which become obsolete above, leaving the upper part of the valve marked only by concentric striæ.

Illinois, Iowa, Nevada, Manitoba.

FIG. 339. *Gypidula pseudogaleata* (Pal. N. Y.).

236. **G. romingeri** Hall and Clarke. (Fig. 340.) Devonic.

Large. Pedicle valve very convex; brachial depressed convex. Surface covered with strong plications which frequently bifurcate irregularly toward the front.

Hamilton of Michigan.

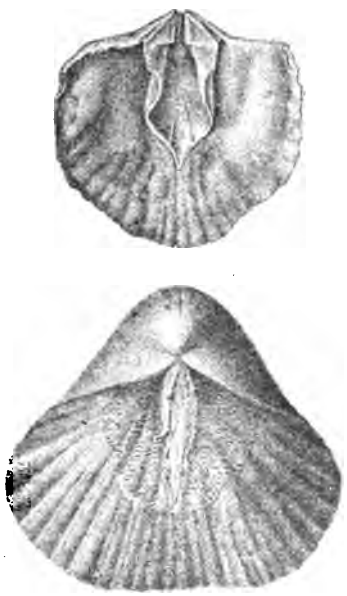


FIG. 340. *Gypidula romingeri*, external view and interior of brachial valve. (After Hall and Clarke.)

LXXI. AMPHIGENIA Hall.

Elongate-ovate, high-shouldered, without median fold or sinus. Pedicle valve with a spondylium, brachial valve with a large hinge plate perforated at the apex by a foramen. Surface marked by concentric growth lines and faint radial striæ. Devonic.

237. **A. elongata** (Vanuxem). (Fig. 341.) Devonic.

More or less gibbous with broadly rounded front. Pedicle valve the more convex; beak closely incurved over the umbo of opposite valve. Both valves often abruptly elevated above the middle. Shell structure punctate.

Oriskany & Onondaga of New York, Michigan, Ontario, etc.

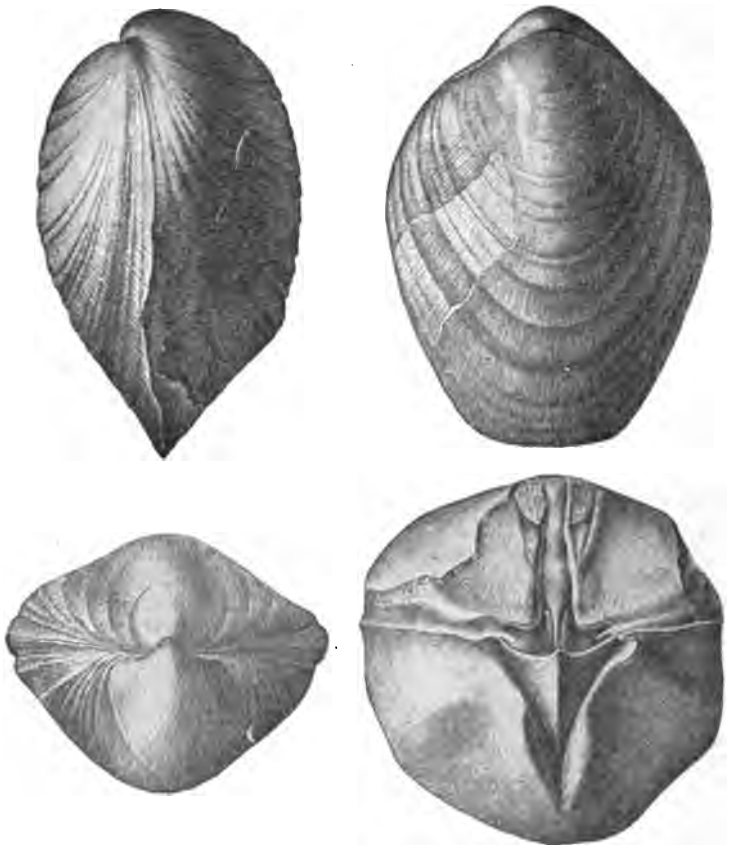


FIG. 341. *Amphigenia elongata* (Pal. N. Y., IV.).

LXXII. CAMAROPHORIA King.

Rhynchonelliform. Surface more or less plicated. Spondylium supportedby a long median septum. Devonic–Carbonic.

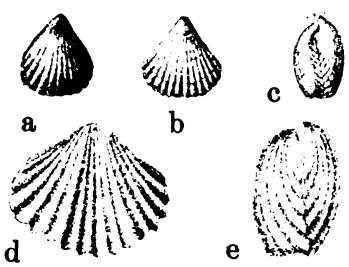


FIG. 342. *a–c, Camarophoria subcuneata.* (AfterWhitfield.) *d–e, Orthorhynchula linneyi.* (After Nettelroth.)

238. **C. subcuneata** Hall. (Fig. 342, *a–c.*) Mississippic. Wedge-shaped with rounded front, nearly equally biconvex. Beak of pedicle valve very acute and but little incurved, perforated by a triangular foramen. Surface marked by 12–14 angular plications, crossed by concentric striæ.

St. Louis of Ohio, Indiana.

TELOTREMATA.

LXXIII. ORTHORHYNCHULA Hall and Clarke.

Rostrate with narrowed beaks. Hinge line straight, extending about one third the transverse diameter of the valves. Cardinal area present on both valves, that of the pedicle valve being the higher; delthyrium open. No dental lamellæ in the pedicle valve. Cardinal process linear. Surface strongly plicate. It thus resembles both *Orthis* and *Rhynchonella*. Ordovicic.

239. **O. linneyi** (James). (Fig. 342, *d*, *e*.) Ordovicic.

Median fold and sinus well developed. Average length $\frac{5}{8}$ inch, width $\frac{6}{8}$ inch, thickness $\frac{1}{2}$ inch.

Lorraine of Kentucky, Tennessee, Ohio.

LXXIV. RHYNCHOTREMA Hall.

Rostrate, thick-shelled. Pedicle valve with apex closely incurved over that of brachial. Teeth strong. Deltidial plates concave, thick, cemented firmly to the bottom of the valve. Brachial valve with a thickened median septum. Cardinal process slender, linear, with broad and stout crural plate on each side. Ordovicic and Devonic.

240. **R. inequivalve** (Castelnau). (Fig. 343, *a–d*.) Ordovicic.

Small. Pedicle valve strongly convex at umbo and nearly flat on each side of the deep median sinus, sloping laterally. Brachial valve more convex than the pedicle. Surface marked with prominent subangular plications, 15–22 on each valve with 3–5 on the fold and 2–5 in the sinus, crossed by very delicate concentric zigzag lines.

Trenton. Widely distributed throughout North America.

241. **R. dentatum** Hall. (Fig. 343, *e–g*.) Ordovicic.

Pyramidal with breadth somewhat greater than length. Beak of pedicle valve small and acute, closely incurved over that of the brachial valve. Pedicle valve with a broad, deep and angular sinus, strongly elevated toward the front. Surface marked by 8 or 9 strong and deep plications, two of which are very much elvated on the fold of the brachial valve and one of which occupies the sinus of the pedicle valve.

Trenton and Lorraine of New York, Tennessee, Ohio, Indiana.

242. **R. capax** (Conrad). (Fig. 343, *h–k.*) Ordovicic.

Beak of pedicle valve closely incurved over that of brachial. Apex of pedicle valve usually perforated by a small pedicle opening. Three (rarely 4) angular plications occupy the very promi-

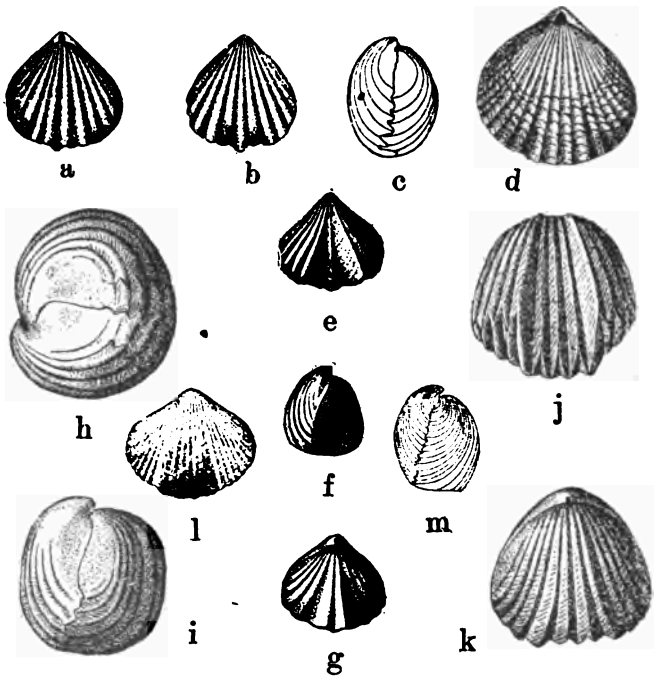


FIG. 343. *a–d, Rhynchotrema inequivalve* (Min. Survey); *e–g, Rhynchotrema dentatum* (Ind. Survey); *h–k, Rhynchotrema capax* (Ind. Survey); *l–m, Rhynchotrema ainslii* (Min. Survey).

nent sinus and 4 the corresponding fold on the brachial valve. The angular radiating plications are crossed by many strongly zigzag growth lines.

Lorraine; widely distributed throughout North America.

243. **R. ainslii** N. H. Winchell. (Fig. 343, *l–m.*) Ordovicic.

Differs from *R. inæquivalve* in being usually larger, more transverse, and in having 28 to 34 plications with 6 to 8 on the fold.

Trenton of Iowa and Minnesota.

LXXV. RHYNCHOTRETA Hall.

Elongate triangular, marked with angular plications. Beak of pedicle valve acuminate and produced beyond that of opposite

valve. Pedicle valve at first with a median fold which later becomes a sinus; the brachial valve likewise reverses its early median sinus into a fold. Two elevated and longitudinally striated deltidial plates fill the delthyrium. Siluric.

244. **R. cuneata americana** Hall. (Fig. 344.) Siluric.

Wedge-shaped. Beak of pedicle valve angular with compressed sides. Deep frontal emargination extends as a broad sinus two thirds of the distance to the beak. Plications crossed by threadlike concentric striæ.

Niagaran of New York, Kentucky, Indiana, Wisconsin, Ontario.

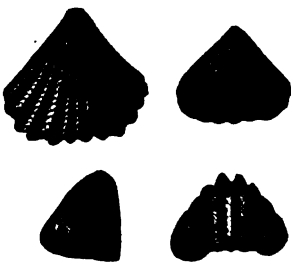


FIG. 344. *Rhynchotreta cuneata* var. *americana* (Pal. N. Y., II.).

LXXVI. CAMAROTŒCHIA Hall and Clarke.

Rhynchonelloid, rostrate. Brachial valve the deeper. Pedicel valve shallow with beak projecting over that of the brachial. Surface radially plicate. Distinctive internal characters are: a median septum in the brachial valve, dividing posteriorly to form an elongate spondylium, no cardinal process. In the pedicle valve slender vertical lamellæ support the teeth. Ordovicic–Mississippic.

A. Small — less than ½ inch wide ..... *.
  * Length and width nearly equal ..... 1.
    1. Round posteriorly ..... 254. *C. dotis.*
    1. Acute posteriorly ..... *a.*
      a. Fold and sinus very conspicuous ..... 246. *C. neglecta.*
      a. Fold and sinus inconspicuous ..... 252. *C. semiplicata.*
  * Length exceeding width ..... 247. *C. acinus.*
  * Width exceeding length. Surface rugose. ..... 250. *C. lamellata.*
B. Of medium size — ½ inch or more wide ..... **.
  ** Transversely oval, *i. e.*, width exceeding length ..... 2.
    2. Plications angular, numerous (20–24), of which 4–7 mark the mesial sinus and fold ..... *b.*
      b. Plications coarse and prominent ..... 256. *C. sappho.*
      b. Plications fine ..... 255. *C. horsfordi.*
    2. Plications obtuse, few (about 16), of which 2 or 3 mark the sinus and fold ..... 258. *C. sageriana.*
  ** Somewhat quadrangular, *i. e.*, with length and breadth nearly equal ..... 3.
    3. Both valves noticeably convex ..... *c.*
      c. Plications numerous (14–20) ..... 1′.
        1′. Shell ventricose, thickness equal to or greater than length. 272. *C.* (*Wilsonia*) *ventricosa.*

1′. Shell not ventricose ..... *a′*.
a′. Pedicle valve with small, closely incurved beak.
245. *C. plena*.
a′. Pedicle valve with large, not closely incurved beak.
251. *C. litchfieldensis*.
c. Plications few (9–14) ..... 2′.
2′. Angle at beak between cardinal slopes less than 90°.
248. *C. indianensis*.
2′. Angle at beak greater than 90° ..... 249. *C. whitei*.
3. Pedicle valve flattened ..... *d*.
d. Sinus and fold with 2–4 plications ..... 257. *C. contracta*.
d. Sinus and fold with 5 or 6 plications ..... 253. *C. tethys*.

245. **C. plena** Hall. (Fig. 345.) Ordovicic.

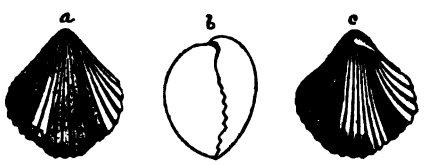


FIG. 345. *Camarotœchia plena* (Canadian Geol. Surv.).

Gibbous. Pedicle valve with small beak, closely incurved over that of the brachial valve. Surface of each valve marked with 16–20 strong radial plications, about 4 or 5 of which occupy the sinus and fold.

Chazy of New York, Ontario, Quebec.

246. **C. neglecta** Hall. (Fig. 346.) Siluric.

Small. Brachial valve the more convex. Sides sloping abruptly from beak. Plications 8–13. Strongly defined sinus and fold, the former with 3, the latter with 4 plications. Deep frontal emargination present.

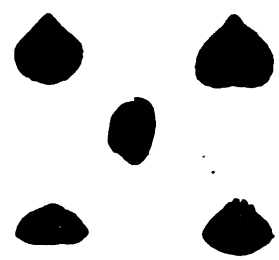


FIG. 346. *Camarotœchia neglecta* (Pal. N. Y. II.).

Clinton and Niagaran of New York, Ohio, Indiana, Wisconsin, Ontario, Nova Scotia.

247. **C. acinus** Hall. (Figs. 347, 348, upper row.) Siluric.

Small, longitudinally ovate, narrowed toward the beak and truncate in front. Valves of nearly equal convexity. Surface marked by few plications of which there is one in the very low sinus of the pedicle valve and two in the inconspicuous fold of the brachial.

Clinton of New York, Niagara of Indiana, Kentucky.

248. **C. indianensis** (Hall). (Fig. 348, middle row.) Siluric.

Subtriangular, moderately biconvex. Length and width nearly

equal (about ½ inch). Pedicle valve with pointed and incurved beak. Surface marked by 9–12 strong plications of which 2–3 occupy the sinus and 3–4 the fold. Differs from *C. neglecta* in

FIG. 347. *Camarotœchia acinus.* A specimen in which the fold and sinus are no developed. Enlarged, × 4. Clinton. (After Grabau.)

being larger and more robust with stronger and less angular plications.

Niagaran of Kentucky, Indiana.

249. **C. whitei** Hall. (Fig. 348, lower row.) Siluric.

Somewhat quadrangular. Pedicle valve with beak abruptly attenuate and pointed; sides flattened. Surface marked with five to

FIG. 348. (Upper row) *Camarotœchia acinus,* × 4: (middle row) *Camarotœchia indianensis*; (lower row) *Camarotœchia whitei.* (After Hall.)

six plications on each side of median sinus and fold, with usually but one plication in the sinus and two on the fold. Interspaces wider than plications. Concentric growth lines close.

Niagaran of Indiana.

250. **C. lamellata** Hall. (Fig. 349.) Siluric.

Small, subrhomboidal. Surface with six to seven simple plications on each side of fold and sinus; usually but two plications in sinus and three on fold. Entire shell crossed by strong, imbricating, concentric lamellæ which are conspicuously arched over the plications, giving the surface a rugose appearance.

FIG. 349. *Camarotæchia lamellata* (Pal. N. Y. II.).

Upper Siluric (Cobleskill, etc.) of New York, New Jersey, Pennsylvania, Maryland and West Virginia.

251. **C. litchfieldensis** Schuchert. (Fig. 350.) Siluric.

Large, robust. Length and breadth subequal. Umbo of pedicle valve large and prominent. Surface with 16 to 18 plications,

FIG. 350. *Camarotæchia litchfieldensis.* (After Schuchert.)

of which three and four occupy respectively the rather narrow and unpronounced sinus and fold.

Cobleskill and Rondout of New York.

252. **C. semiplicata** (Conrad). (Fig. 351.) Devonic.

Subtriangular. Valves nearly equal. Surface smooth in upper portion with low plications toward the front, one to two of which occupy the shallow sinus and two to three the low fold; a few (one to four) are present on each side of fold and sinus. Very similar to *C. acinus*, but the angle at the beak between the cardinal slope is larger, the sinus and fold are more pronounced and the shell is larger, averaging about $\frac{5}{16}$ inch in length, while *C. acinus* averages only about $\frac{3}{16}$ inch.

FIG. 351. *Camarotæchia semiplicata* (Pal. N. Y. III.).

Helderbergian (Coeymans) of New York.

253. **C. tethys** (Billings). (Fig. 352, *a–c.*) Devonic.

Differs from *C. contracta* in its subtrigonal form and broader sinus and fold which here bear 5 or 6 plications each.

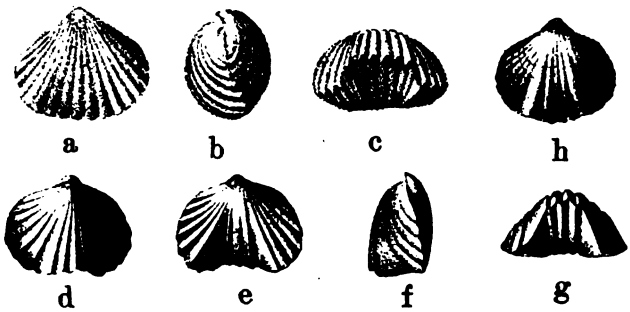


FIG. 352. *a-c, Camarotœchia tethys.* (After Nettelroth.) *d-g, Camarotœchia contracta* (Pal. N. Y. IV.). *h, Leiorhynchus sinuatum.* (After Walcott.)

Onondaga of New York, Ohio, Kentucky, Indiana, Nevada, Ontario.

254. **C. dotis** Hall. (Fig. 353.) Devonic.

Subtriangularly ovate with shallow sinus and moderate fold. Pedicle valve slightly flattened at the sides. Plications about 18 in number of which there are 3 or 4 in the sinus and 4 or 5 on the fold.

Marcellus and Hamilton of New York, Ohio.

FIG. 353. *Camarotœchia dotis.* (Grabau.)

255. **C. horsfordi** Hall. (Fig. 354, *a, b.*) Devonic.

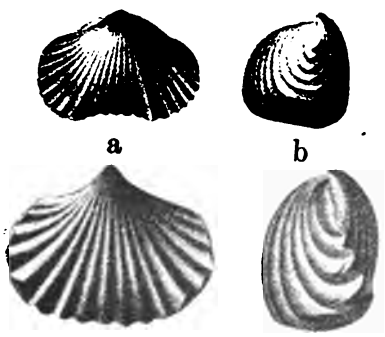


FIG. 354. *a-b, Camarotœchia horsfordi; c-d, Camarotœchia sappho* (Pal. N.Y.IV.).

Length to width as 5 to 6 or7. Brachial valve very convex. Pedicle valve depressed-convex with sinus appearing first at about the middle of the shell, abruptly curved upward in front. 15-24 angular plications on each valve of which 4–7 mark the sinus and fold.

Marcellus and Hamilton of New York, Nevada.

256. **C. sappho** Hall. (Fig. 354, *c, d.*) Devonic–Mississippic.

Large and robust, broader than long. Pedicle valve depressed-convex with abruptly acute apex. Brachial valve gibbous, regularly arching transversely. Surface marked with 20–24 strong, angular plications.

Marcellus-Waverly of New York, Ohio.

257. **C. contracta** Hall. (Fig. 352, *d–g.*) Devonic–Mississippic.

Subquadrate, abruptly and deeply sinuate. Pedicle valve very slightly convex, often becoming almost flat near the front and marked by a broad angular sinus. Brachial valve somewhat gibbous in the middle and regularly convex transversely, marked by a mesial fold. Surface with 16–20 angular plications of which there are 4 on fold and 3 in sinus.

Portage-Waverly of New York, Pennsylvania, Ohio.

258. **C. sageriana** (A. Winchell). Mississippic.

Of medium size. Brachial valve quite convex with a prominent and inflected beak and about 16 obtuse radial plications, some of the central ones showing a groove on the summit toward the front. Mesial fold developed only at front of valve where it consists of 2 or 3 slightly elevated plications.

Marshall of Michigan, Waverly of Tennessee, Ohio.

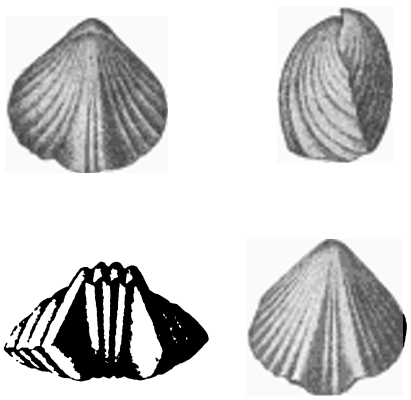


FIG. 355. *Stenochisma formosum* (Pal. N. Y. III.).

LXXVII. STENOCHISMA.

Differs from *Camarotœchia* in wanting the median septum of the brachial valve with its subcardinal cavity; and in having the hinge plate divided by a median fissure which extends to the bottom of the shell and contains a slender cardinal process. Devonic.

259. **S. formosum** (Hall). (Fig. 355.) Devonic

Subtriangular, the lateral margins forming an angle at the beak of 90° to 110°. Beak of pedicle valve prominent and arched. Brachial valve the more convex. Surface marked with 20 to 24 simple, angular plications on each valve, 2 to 4 of which occupy sinus and fold.

Helderbergian of New York, New Brunswick and Nova Scotia.

LXXVIII. Leiorhynchus Hall.

Similar to *Camarotœchia* but with the plications on the median fold and sinus highly developed while those on the lateral slopes are slightly developed or wanting. Shell substance thin. Dev.–Miss.

260. **L. mysia** Hall. (Fig. 356.) Devonic.

Very small, usually not exceeding 3/8 inch in diameter, with almost circular outline and with proportionally very strong plications of which there is at least one in the sinus with at least three on each side of it.

Marcellus of New York.

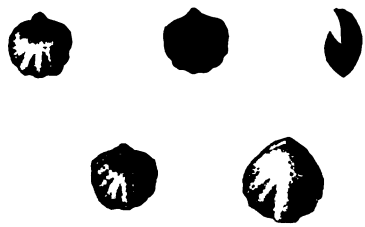


Fig. 356. *Leiorhynchus mysia* (Pal. N. Y. IV.).

261. **L. limitare** (Vanuxem). (Fig. 357, *a–b.*) Devonic.

Small, gibbous, with mesial sinus and fold developed toward the front. Plications on fold and sinus bifurcating. Surface plications covered with fine concentric striæ.

Marcellus of New York, Ohio.

262. **L. laura** (Billings). (Fig. 357, *c.*) Devonic.

Length and greatest width nearly equal. Sinus and fold marked with 3 to 7 rounded plications, all bifurcating. Concentric striæ present.

Marcellus-Hamilton of New York, Nevada, Ontario.

Fig. 357. *a–b, Leiorhynchus limitare; c, L. laura; d, L. quadricostatum.*

263. **L. quadricostatum** (Vanuxem). (Fig. 357, *d.*) Devonic.

Broadly ovate. Plications of lateral slopes very faint. Sinus and fold marked with 3 to 5 rounded plications.

Genesee of New York, Indiana, Kentucky, Nevada.

264. **L. sinuatum** Hall. (Fig. 352, *h.*) Devonic

Differs from *L. limitare* in its larger size and more robust development and in its coarser plications which do not extend to the beak.

Chemung of New York, Nevada.

LXXIX. Uncinulus Bayle.

Subcuboidal with an abrupt anterior slope. Fold and sinus sharply developed only at anterior margin. Plications low, marked anteriorly by a faint median line. Muscular scars of pedicle valve very large and deep. Hinge plate of brachial valve undivided. Cardinal process well developed, bifid or simple. Median septum well developed. Siluric–Devonic.

A. Plications numerous, about 25 to 36 ..... *.
  * Median fold rather prominent ..... 1.
    1. Sides and front abruptly deflected ..... *a.*
      a. Sinus comparatively narrow ..... 270. *U. vellicatus.*
      a. Sinus comparatively broad ..... 269. *U. abruptus.*
    1. Sides and front rounded, not abruptly deflected ..... 265. *U. stricklandi.*
  * Median fold, rounded, not prominent ..... 271. *U. nobilis.*

B. Plications few, about 15 to 25 ..... **.
  ** Pedicle valve depressed-convex ..... 2.
    2. Brachial valve declining regularly from front to beak ... 267. *U. nucleolatus*
    2. Brachial valve declining more abruptly near the beak. 266. *U. campbellanus.*
  ** Pedicle valve convex ..... 268. *U. mutabilis.*

265. **U. stricklandi** (Sowerby). (Fig. 358.) Siluric.

Large (about 1 inch long), ovate very convex. Length and breadth about equal. Sides and front rounded. Pedicle valve de-

Fig. 358. *Uncinulus stricklandi.* (After Hall.)

pressed-convex; beak small, closely incurved over that of the opposite valve; mesial sinus wide, deep in front. Brachial valve gibbous; mesial fold wide, prominent anteriorly. Surface marked

by 25–35 simple angular plications of which 6–8 occupy fold and sinus.

Niagaran of Kentucky, Indiana.

266. **U. campbellanus** (Hall). (Fig. 359.) Devonic.

Laterally compressed. Width $\frac{2}{3}$ length. Brachial valve the larger, elevated near front into a broad undefined mesial fold, curving abruptly at sides. Pedicle valve with a broad shallow

FIG. 359. *Uncinulus campbellanus* (Pal. N. Y., III.).

sinus towards the front; lateral margins of valve abruptly deflected toward opposite valve, thus giving the sides of the shell a flattened appearance. Surface marked by 20–26 simple plications.

Helderbergian (Becraft) of New York.

267. **U. nucleolatus** Hall. (Fig. 360.) Devonic.

Subspherical, declining towards the beak. Pedicle valve depressed convex, abruptly deflected towards margins; brachial valve very convex anteriorly, depressed posteriorly. Surface

FIG. 360. *Uncinulus nucleolatus* (Pal. N. Y., III.).

marked by 15–23 simple plications about 4 or 5 of which, by their slight elevation on the brachial valve and their depression on the pedicle valve form a more or less distinct fold and sinus.

Helderbergian (New Scotland) of Maine, New York, New Brunswick.

268. **U. mutabilis** Hall. (Fig. 361.) Devonic.

Ovate to spherical. Beak of pedicle valve small, pointed and closely incurved over the opposite valve. Beak of brachial valve incurved beyond the hinge line. Cardinal border on each side of

the beak concave. Surface bearing numerous (20–26) low, rounded, simple plications of which six and five occupy respectively the fold and sinus.

Helderbergian (Coeymans) of New York.

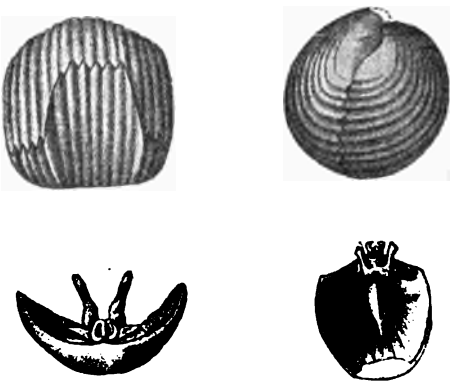


FIG. 361. *Uncinulus mutabilis* (Pal. N. Y., III.).

269. **U. abruptus** Hall. (Fig. 362.) Devonic.

Transversely oval. Pedicle valve depressed-convex and very abruptly deflected (almost at a right angle) toward the opposite valve on the lateral and anterior margins; beak small, closely incurved. Brachial valve very prominent in front; beak depressed.

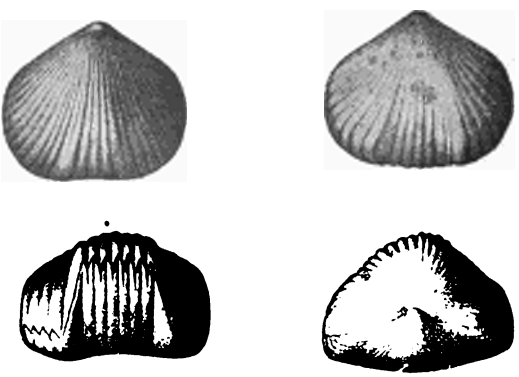


FIG. 362. *Uncinulus abruptus* (Pal. N. Y., III.).

Surface with 25 to 33 simple, subangular plications; the low but distinct fold and sinus occupied by about 7 and 6 respectively.

Helderbergian (New Scotland) of New York.

270. **U. vellicatus** Hall. (Fig. 363.) Devonic.

Pedicle valve depressed-convex. Brachial valve gibbous in front, depressed and rounded toward the beak. Surface with 24 to 36 plications of which 6 to 8 occupy fold and 5 to 7 the sinus. Differs from *U. abruptus* in its smaller size, its smaller and more numerous plications; also in being less ventricose, due to its narrower and more pronounced median sinus and fold and its posteriorly less convex brachial valve.

FIG. 363. *Uncinulus vellicatus* (Pal. N. Y., III.).

Helderbergian (New Scotland) of New York and New Brunswick.

271. **U. nobilis** Hall. (Fig. 364.) Devonic.

Pedicle valve depressed-convex; brachial valve declining laterally with an abrupt curve to meet the inflected margin of the pedicle valve; its umbo rather prominent and incurved. Surface marked with 26 to 32 strong, angular plications, six to eight of which occupy the rounded mesial fold and 5 to 7 the rounded sinus. This species is more elongate than *U. abruptus* and less than *U. campbellanus*.

FIG. 364. *Uncinulus nobilis* (Pal. N. Y., III.).

Helderbergian (Becraft) of New York and Pennsylvania.

LXXX. WILSONIA Kayser.

Hingeplate small, divided by a shallow median incision; no cardinal process; otherwise like *Uncinulus*, from which it is indistinguishable by external characters. Siluric to Devonic.

272. **W. ventricosa** (Hall). (Fig. 365.) Devonic.

Spheroidal, ventricose. Cardinal region on each side of the beak elevated. Beak of pedicle valve rather small and obtuse, closely incurved. Surface with 14 to 20 low, rounded plications. Very inconspicuous sinus and fold at times present, occupied by two to four plications. Front of plications marked by a longitudinal

depressed line. Differs from *Uncinulus nucleolatus* externally in having stronger plications.

Helderbergian (Becraft) of New York.

FIG. 365. *Wilsonia ventricosa* (Pal. N. Y., III.).

LXXXI. HYPOTHYRIS King.

Subcuboidal, with plications. Similar to *Uncinulus* but muscular scars of pedicle valve are small and faint and the septum in brachial valve is very faint. Devonic.

273. **H. emmonsi** (Hall and Whitfield). Middle Devonic.

Squarely truncate in front. Pedicle valve depressed-convex; beak small, projecting; median sinus very broad, at front abruptly bent upward in a broad linguiform extension nearly equal to the entire height of the shell and about two thirds as wide as the width of the shell; the sides of this extension are straight and parallel

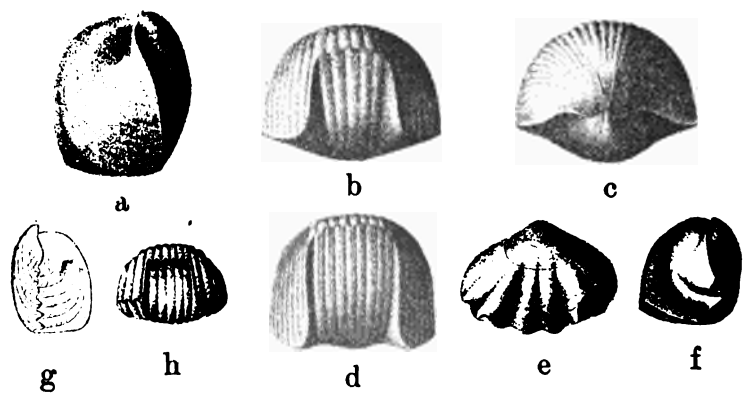


FIG. 366. *a–d, Hypothyris cuboides* (Pal. N. Y., IV.); *e–f, Pugnax pugnus* (Pal. N. Y., IV.); *g–h, Pugnax grosvenori* (Ind. Geol. Survey).

almost to the top. Brachial valve very convex. Surface marked by about 25 low rounded plications on each side of the mesial fold and sinus with about 14 in each of the latter.

Iowa, Nevada, Athabasca.

274. **H. cuboides** (Sowerby). (Fig. 366, *a–d.*) Devonic.

Pedicle valve slightly less convex than the brachial and abruptly depressed in a broad deep sinus. Umbo moderately elevated with minute and closely appressed beak. Brachial valve very gibbous with a defined mesial fold reaching above the middle of the shell and sharply truncate in front, bearing 6 or 7 plications. Whole surface covered with plications which are crossed by fine concentric striæ.

Tully of New York, Manitoba; Europe.

LXXXII. PUGNAX Hall and Clarke.

Pedicle valve shallow with a deep median sinus. Brachial valve deep with a much elevated median fold. Plications on lateral slopes often obscure. Otherwise resembling *Hypothyris*. Upper Devonic–Carbonic.

275. **P. pugnus** (Martin). (Fig. 366, *e–f.*) Upper Devonic.

Transversely ovate, *i. e.*, wider than long. Pedicle valve with small, much incurved beak. Each valve has 9–14 plications which become obsolete as they approach the umbo; from 3–6 occupy fold and sinus. Length and breadth about 1 by 1½ inches.

New York, Nevada, Texas, Northwest Territory.

276. **P. striatocostata** (Meek and Worthen). Mississippic.

Subpentagonal, moderately gibbous, with length and breadth about equal. Plications 9 to 11, broad and distinct, all except the outer ones extending nearly to the umbos. Whole surface covered with distinct radiating striæ and fine concentric lines.

Kinderhook of Missouri.

277. **P. grosvenori** Hall. (Fig. 366, *g–h.*) Mississippic

Subglobose. Beak of pedicle valve small and nearly straight; that of brachial valve obtuse and closely incurved, meeting the opposite valve nearly at a right angle. Surface marked by 14–18 plications about 5 of which mark fold and sinus.

St. Louis of Kentucky, Indiana, Illinois.

FIG. 367. *Pugnax utah* (Ind. Geol. Survey).

278. **P. utah** (Marcou). (Fig. 367.) Carbonic.

Small, emarginate anteriorly. Plications angular, rarely exceeding 9 in number, of which 2–3 are on sinus and fold.

Indiana, Illinois, Iowa, Missouri, Kansas, Arkansas, Nebraska, Utah.

LXXXIII. EATONIA Hall.

Anterior margin deeply sinuate. Pedicle valve nearly flat with a broad deep sinus and small, perforate beak; muscle scars large and deeply excavated. Brachial valve convex and often ventricose; cardinal process very long, resting upon a short median septum and bifid at summit. Differs from *Rhynchonella* in the absence of dental plates, in the presence of a cardinal process and in the stronger muscle impressions of the pedicle valve. Devonic.

279. **E. medialis** (Vanuxem). (Fig. 368.) Devonic.

Hinge line nearly straight. Brachial valve regularly convex from beak to front and elevated into a broad median fold. Pedicle valve somewhat convex at umbo and thence concave to the front

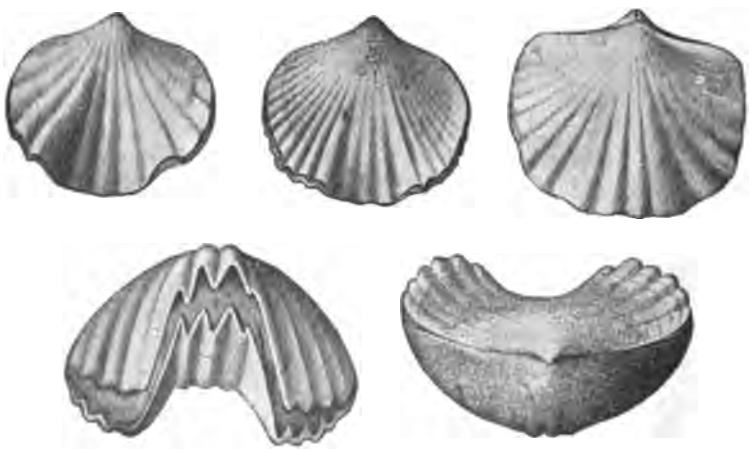


FIG. 368. *Eatonia medialis* (Pal. N. Y., III.).

and depressed into a broad sinus. Surface marked by 12–16 broad plications of which 4 are on the summit of the fold and 3 in the bottom of the sinus.

Helderbergian of Maine, New York.

280. **E. peculiaris** (Conrad). (Fig. 369.) Devonic.

Longitudinally ovate. Hinge line much shorter and more rounded than in *E. medialis;* the mesial fold and sinus are much less pronounced and the margins of the valves are denticulate. Surface marked by fine radiating striæ.

Helderbergian and Oriskanian of New York, Pennsylvania, Maryland, Missouri, Quebec.

LXXXIV. Rhynchopora King.

Resembles *Camarotœchia* but differs externally in its punctate shell structure. Mississippic.

281. **R. pustulosa** (White). Mississippic.

Small, biconvex. Front broadly rounded. Cardinal slopes straightened. Surface marked by 16–22 simple rounded plications five of which are on the sinus and fold each.

Kinderhook of Iowa, Utah, New Mexico.

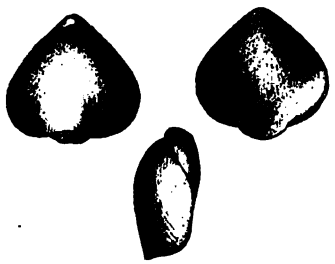


Fig. 369. *Eatonia peculiaris* (Pal. N. Y., III.).

LXXXV. Rhynchonella Fischer de Waldheim.

Rostrate, subpyramidal. Apex of pedicle valve but slightly incurved. Prominent median sinus present on pedicle valve and fold on brachial in typical species. In pedicle valve deltidial plates conspicuous; dental lamellæ present. In brachial valve a median septum present; no cardinal process and no arm supports except crura. Surface radially plicated. Ordovicic(?)–Eocenic.

A. Plications present only upon anterior portion of shell ..... 285. *R. æquiplicata.*
B. Plications present upon entire shell ..... *.
* Outline subtrigonal. Shell less than 1 inch wide ..... 1.
1. Median sinus bearing less than 6 plications .....286. *R. gnathophora.*
1. Median sinus bearing 6 or more plications..... *a.*
a. Surface with 20 to 25 plications.....283. *R. hubbardi.*
a. Surface with more than 20 to 25 plications ..... 1′.
1′. Shell small, a half inch or less in width ... 282. *R. eurekaensis.*
1′. Shell of medium size, more than a half inch in width.
284. *R. myrina.*

282. **R. eurekaensis** Walcott. (Fig. 370.) Mississippic.

Small, subtrigonal in outline. Width and length subequal. Brachial valve slightly deeper than pedicle. Pedicle valve with a prominent, projecting beak and with a rather shallow sinus that forms about half the width of the shell anteriorly. Brachial valve with a slight median fold; umbo strongly incurved. Surface of each valve with 40 to 50 round, simple plications.

Nevada; Arkansas? (Spring creek limestone).

283. **R. hubbardi** A. Winchell. Mississippic.

Small. Cardinal slopes straight. Greatest width about the middle of the shell. The two valves equally convex. Front gently rounded. Pedicle valve with a broad, shallow sinus occupied by 8 or 9 plications. Brachial valve with no fold perceptible but with a shallowsinus extending from the beak for about one third the length of the shell. Surface covered with about 21 narrow plications.

FIG. 370. *Rhynchonella eurekaensis.* (After Walcott.)

Waverly of Ohio, Marshall of Michigan.

284. **R. myrina** Hall and Whitfield. Jurassic.

Of medium size, broadly ovate with greatest diameter below the middle. Brachial valve the deeper, nearly evenly convex from beak to front and with a slightly elevated median fold. Pedicle valve with a prominent projecting beak and a broad, moderately depressed median sinus. Surface marked by 31–34 low, rounded plications, 8–10 of which occupy the fold and sinus.

Dakota, Utah.

285. **R. æquiplicata** Gabb. Triassic.

Subglobose. Valves equally convex. Beak large, prominent and incurved. Sides sloping convexly to extremities of hinge line. Surface with about 14 nearly equal, rounded ribs, beginning on each valve about one third the distance from beak to front; the furrows equalling the ribs in width. Length and width about 1 inch each but length slightly exceeding width. Growth lines faintly developed.

Trias of Humbolt Mt., Nevada.

286. **R. gnathophora** Meek. Jurassic.

Of medium size, subtrigonal, with greatest convexity near the middle. Postero-lateral margins straight, diverging from beak. at an angle of 80° to 100°. Brachial valve usually the more convex, especially near the front where it rises into a median fold traceable for about half the way toward the incurved beak. Pedicle valve with a corresponding sinus; beak pointed. Surface with 16 to 20 simple plications of which three or four are in the sinus and four or five on the fold. Length about .8 inch and breadth about .7 inch.

Jurassic of California and Utah.

LXXXVI. Peregrinella Œhlers.

Shell large, pedicle valve generally the more convex. Valves without median fold or sinus; with even margins and plicated surfaces. Beak short, false cardinal area and deltarium present. Cretacic.

287. **P. whitneyi** (Gabb.). (Fig. 371.) Cretacic.

Large, subcircular in outline; the two valves about equally convex. No median fold or sinus present. Surface marked with 40 to 50 narrow, angular plications which are equal in breadth to the deep, angular interspaces. When young the shell is much longer than wide. Length and breadth eachabout 1¼ inches in maturity.

Knoxville of California.

Fig. 371. *Perigrinella whitneyi.* (After Stanton.)

LXXXVII. Centronella Billings.

Usually small, terebratuloid in outline. Pedicle valve convex, angular in the center; beak acute and incurved with a terminal foramen, which is continuous with a partially closed delthyrium. Brachial valve plane or concave, depressed into a median sinus. Brachidium in two branches uniting medially into a triangular plate bearing a median ridge. Devonic–Mississippic.

288. **C. glansfagea** Hall. (Fig. 372, *a–c.*) Devonic.

Very small, broadly ovate. Pedicle valve much the larger, regularly arcuate from beak to front; beak much extended and strongly incurved. Brachial valve convex above and concave in

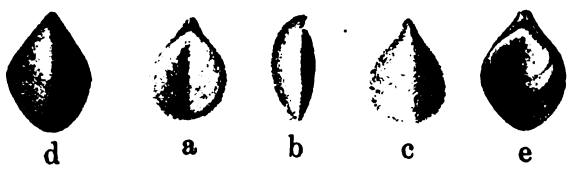


Fig. 272. *a–c, Centronella glansfagea.* (After Nettelroth.) *d–e, C. impressa* (Pal. N. Y., IV.).

the middle through a broad, undefined sinus; beak not incurved. Surface smooth or with faint concentric growth lines.

Oriskany–Onondaga of New York, Kentucky, Indiana, Michigan, Ontario.

289. **C. impressa** Hall. (Fig. 372, *d–e.*) Devonic.

Pedicle valve angularly convex. Brachial valve small with front produced and curved downward to fill the sinuosity in the front of the pedicle valve. Surface covered with fine concentric and faint radiating striæ.

Hamilton of New York.

LXXXVIII. Rensselæria Hall.

Oval or suborbicular, usually gibbous. Beak of pedicle valve prominent, acute and incurved. Valves without mesial fold or sinus. Brachial valve with large hinge plate; brachidium forming a broad plate anteriorly and giving off two small, rod-like processes posteriorly. Surface radially striated or finely plicated. Shell structure punctate. Devonic.

290. **R. æquiradiata** (Conrad). Devonic.

Elliptical with nearly equal valves. Pedicle valve often subangular along the center toward the umbo, with beak incurving over that of the opposite valve. Surface marked by simple radiating striæ, which are most conspicuous near the margin.

Helderbergian of New York, Nova Scotia.

Fig. 373. *Rensselæria ovoides* (Pal. N. Y., III.).

291. **R. ovoides** (Eaton). (Fig. 373.) Devonic.

Length usually much exceeding the breadth, broadest above the

middle and abruptly rounded toward the cardinal extremities, narrowing toward the front. Surface marked by simple radiating striæ. Distinguished from *R. æquiradiata* by its different form, larger size and more prominent striæ.

Oriskany of New York, Pennsylvania, Maryland, Virginia, Quebec.

292. **R. cayuga** Hall and Clarke. (Fig. 374.) Devonic.

Lenticular, often large, suboval in marginal outline. Valves subequally biconvex. Very similar to *R. æquiradiata*, from which it differs principally in its suboval marginal outline and in its large size.

Upper Oriskany (Decewville) of Ontario.

FIG. 374. *Rensselæria cayuga.* (After Hall and Clarke.)

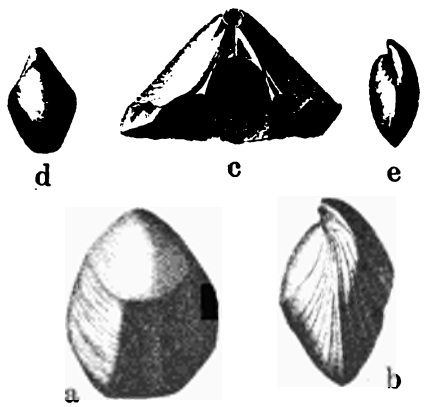


FIG. 375. *a–c, Cryptonella planirostris* with beak of pedicle valve enlarged; *d–e, C. rectirostris* (Pal. N. Y., IV.).

LXXXIX. CRYPTONELLA Hall.

Elongate-oval, unequally convex, usually without median fold or sinus. Pedicle valve with extended and incurved beak, perforated by a terminal foramen. Surface smooth or marked by concentric striæ. Shell structure finely punctate. Devonic–Mississippic.

293. **C. planirostris** Hall. (Fig. 375, *a–c.*) Devonic.

Often subpentagonal in outline. Pedicle valve with moderately incurved beak. Brachial valve much shorter than the pedicle. Surface marked by fine concentric striæ.

Marcellus, Hamilton of New York.

294. **C. rectirostris** Hall. (Fig. 375, *d–e.*) Devonic.

Distinguished from *C. planirostris* by its more elongate form and extended and attenuate beak.

Hamilton of New York, Kentucky, Indiana.

XC. Dielasma King.

Terebratuloid. Pedicle valve with a large foramen. Brachial valve with a large, anteriorly acuminate hinge plate (muscular platform) raised but little above the bottom of the valve and sometimes actually adhering to it. Brachidium a relatively short and simple loop, consisting of descending lamellæ, and a backward arching transverse band. Devonic–Carbonic.

295. **D. (Cranæna) romingeri** Hall. (Fig. 376, *a–c.*) Devonic.

Small, ovate, with rounded cardinal slopes. Concentric striæ often crowded into wrinkles near the front.

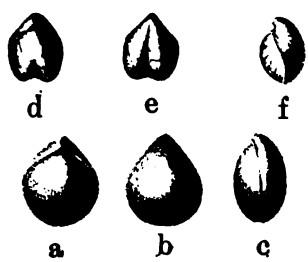


Fig. 376. *a–c*, *Dielasma* (*Cranæna*) *romingeri* (Pal. N. Y., IV.); *d–f*, *D. turgidum*. (After Whitfield.)

Hamilton of New York, Michigan, Indiana, Iowa.

296. **D. calvini** (Hall and Whitfield). Devonic.

Shell about 1½ inches long by 1¼ inches wide and about ⅝ inch in greatest thickness. Pedicle valve with umbo curved so that its foramen is at right angles to the plane of separation of the valves. Brachial valve usually with a median fold near the front. Surface smooth except for a few concentric growth lines.

Chemung of Iowa, Northwest Territory.

297. **D. turgidum** (Hall). (Fig. 376, *d–f.*) Mississippic.

Longitudinally ovate, often very gibbous, emarginate in front. Sinus present in pedicle valve and sometimes in brachial. Surface marked by strong concentric growth-lines and occasionally by strong wrinkles in the anterior portion. Differs from *D. romingeri* in its greater gibbosity and in the more strongly marked sinus of the pedicle valve.

Warsaw and St. Louis of Ohio, Kentucky, Indiana, Illinois, Missouri, Iowa.

298. **D. bovidens** (Morton). (Fig. 377.) Carbonic.

Elongate, ovate, averaging about ¾ inch in length by ½ inch in breadth. Pedicle valve strongly arcuate with prominent, incurved beak and broad mesial sinus, extending anteriorly from the middle of the valve. Brachial valve almost straight along the median line from the anterior margin to about the middle where it begins to curve gently to the beak; mesial fold usually entirely lacking. Surface nearly smooth. This is larger than *D. romingeri* and lacks its broader ovate character. It differs from *D. turgidum* in its larger size, less gibbous form and less emargin anterior portion.

FIG. 377. *Dielasma bovidens* (Ind. Geol. Survey).

Widely distributed through the central United States.

XCI. EUNELLA Hall and Clarke.

Differs from *Dielasma* in the absence of the large hinge plate. Devonic.

299. **E. lincklæni** Hall. (Fig. 378.) Devonic.

Terebratuloid. Pedicle valve at times with a narrow mesial depression; beak more or less abruptly incurved; umbonal slopes concave toward the cardinal margin. Surface of both valves marked by fine concentric growth lines. Shell structure punctate.

Marcellus and Hamilton of New York, Michigan, Indiana.

FIG. 378. *Eunella lincklæni.* Views of two individuals showing variation (Pal. N. Y., IV.).

XCII. TEREBRATULA Klein.

Form terebratuloid, elongate biconvex generally with median flattening or depression in each valve. Surface not striate; deltidial plates complete. Loop short, unsupported by a median septum at any stage of growth. (Fig. 380.) Devonic(?)–Recent.

300. **T. ? humboldtensis** Gabb. Triassic.

Of medium size. Front truncate and marked by a simple or double fold and sinus. Pedicle valve slightly flattened across the middle. Beak broad, prominent, but slightly incurved and truncated by a large foramen. Cardinal borders strongly inflected and flattened, forming an angularity along the edge of the beak. Surface smooth except for strong and irregular concentric growth lines.

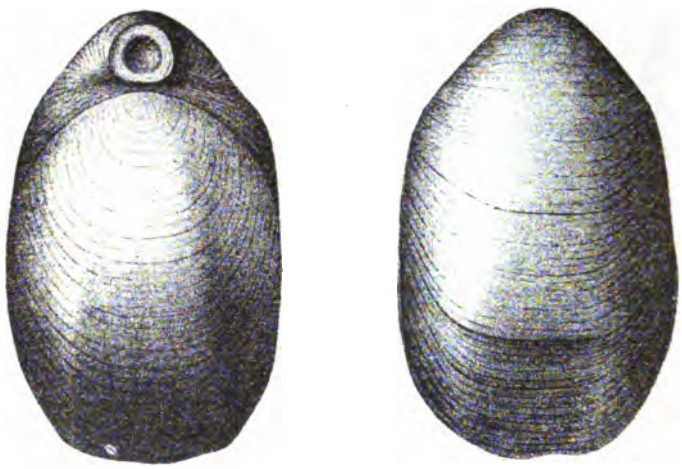


FIG. 379. *Terebratula harlani.* Average sized example. (After Whitfield.)

Triassic of Nevada and Nicola Lake, Canada.

301. **T. harlani** Morton. (Figs. 379 and 380.) Cretacic–Eocenic.

Large (sometimes 2¾ inches long), elongate-oval with subparallel sides. Front more or less truncate, at times slightly bilobate. Valves very ventricose, covered with concentric growth lines. Pedicle valve with large beak, strongly incurved; foramen large. Shell substance finely punctate.

FIG. 380. *Terebratula harlani.* Interior showing loop. (After Whitfield.)

Upper Cretacic (Rancocas) of New Jersey, Delaware, South Carolina. Eocenic of Maryland.

XCIII. TEREBRATULINA d'Orbigny.

Ovate, biconvex. Cardinal extremities faintly auriculate. Pedicle valve with circular foramen; deltidial plates small, generally

incomplete; dental plates wanting. Brachial valve with small cardinal process; hinge plate and median septum wanting; socket walls prominent, supporting a short *Dielasma*-like loop with the crural spines typically united into a transverse band or jugum. Surface finely radiate. Jurassic–Recent.

302. **T. atlantica** (Morton). (Fig. 381.) Cretacic.

Ovate. Valves unequally convex. Length about ¾ inch; width ½ inch. Pedicle valve with large foramen; beak not incurved. Both valves covered with numerous bifurcating striæ.

Upper Cretacic (Manasquan) Staten Island and New Jersey.

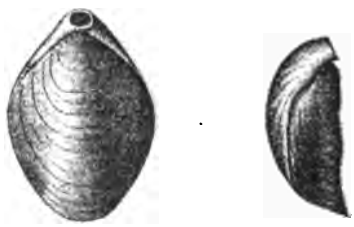


FIG. 381. *Terebratulina atlantica*. (After Whitfield.)

XCIV. TROPIDOLEPTUS Hall.

Form Strophomenoid. Hinge line straight; area well developed. Pedicle valve convex with two broad divergent teeth and open, subcircular delthyrium. Brachial valve concave or flat with large cardinal process bilobed at summit. Teeth and dental sockets corrugated on their outer surfaces. Shell substance highly punctate. Loop of descending lamellæ joining to median septum. Devonic.

303. **T. carinatus** (Conrad). (Fig. 382.) Devonic.

Plications simple, rounded, wider than the interspaces. Central plication of pedicle valve broader and higher than the rest. Concentric striæ fine with occasional coarser imbricating lamellæ.

Marcellus and Hamilton of New York, Pennsylvania, Ohio. Kentucky, Indiana, Illinois. Also foreign.

XCV. KINGENA Davidson.

Subovate, biconvex, inequivalved, terebratuloid in outline, convexity and foramen. In brachial valve a cup-like hollow between the sockets gives rise to a median septum extending about half the length of the valve. Loop more complicated than in *Terebratula*. Shell structure punctate. Comanchic.

304. **K. wacoensis** (Roemer). Comanchic.

Pentagonal, frontal margin straight. Both valves very convex. Pedicle valve with beak greatly incurved and with a distinct car-

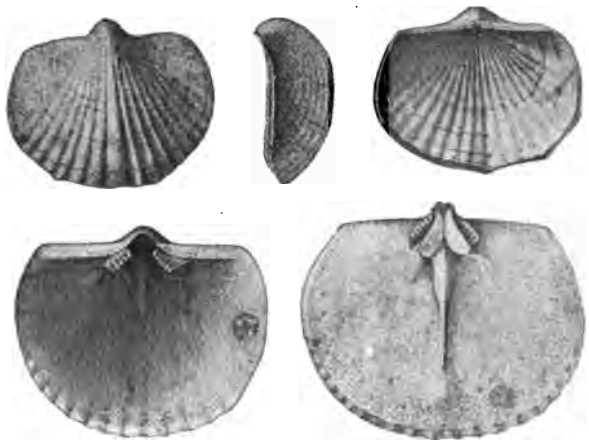


FIG. 382. *Tropidoleptus carinatus.* External and internal views (Pal. N. Y., IV.).

dinal area. Surface marked only with a few concentric growth lines.

Washitan of Texas, Vancouver Island.

XCVI. TEREBRATELLA d'Orbigny.

Plicated Terebratuloids, with straight or slightly curved hinge line. Loop composed of descending and ascending branches, supported by a median dorsal septum throughout life or only in the younger stages. Lias-Recent.

305. **T. plicata** (Say). (Fig. 383.) Cretacic.

Subcircular, somewhat plano-convex, marked by 8–12 or sometimes more, sharply angular plications which extend from beak to

FIG. 383. *Terebratella plicata.* Dorsal and side view; and interior of brachial valve enlarged. (After Whitfield.)

front. Pedicle valve strongly convex with an erect beak of small size; foramen large. Structure strongly punctate.

Upper Cretacic (Matawan and Monmouth) of New Jersey, etc.

306. **T. vanuxemi** Lyell and Forbes. (Fig. 384.) Cretacic.

Valves more convex than preceding, plications more numerous, less angular and less distinct, except occasionally in central portion of valve.

Upper Cretacic (Monmouth) of New Jersey, etc.

FIG. 384. *Terebratella vanuxemi.* Dorsal and side view of average form; dorsal view of more finely plicate form. (After Whitfield.)

XCVII. ZYGOSPIRA Hall.

Subcircular, biconvex. Like *Atrypa* but small and with a median plicated fold in the pedicle valve. Brachial valve marked by a median sinus; cardinal process stout, bilobed. Spirals composed of fewer coils than in *Atrypa* and turned inwards; primary lamellæ united by transverse jugum (Fig. 385, *e*); surface sharply plicate. Ordovic–Siluric–? Devonic.

307. **Z. recurvirostris** (Hall). (Fig. 385, *a–e.*) Ordovicic.

Length slightly exceeding width. Smaller than *Z. modesta.*

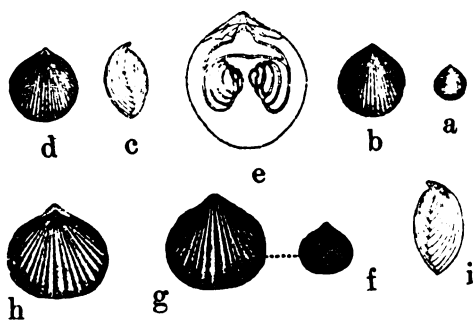


FIG. 385. *a–e, Zygospira recurvirostris;* nat. size and three views enlarged × 2 (*e*) brachidium still more enlarged × 4; *f–i, Zygospira modesta,* natural size and three enlarged views × 2. (After Winchell and Schuchert.

Trenton of New York, Kentucky, Wisconsin, Minnesota, Ontario, Manitoba.

308. **Z. modesta** Hall. (Fig. 385, *f–i.*) Ordovicic.

Width slightly exceeding length. Hinge line somewhat extended. Pedicle valve convex with a median ridge occupied by four stronger plications; beak prominent and incurved. Brachial valve depressed-convex and nearly circular with an ill defined mesial sinus. Plications simple, about 18.

Utica to Richmond of New York, Ohio, Missouri, Wisconsin, Iowa, Minnesota, Ontario. Clinton of Ohio.

308*a*. var. **cincinnatiensis** James. Ordovicic.

Differs of the preceding in its larger size, more pronounced median fold and sinus, and coarser more angular bifurcating plications.

Cincinnatian of Ohio, Tennessee, etc.

309. **Z. nicoletti** Winchell and Schuchert. (Fig. 386, *a–c.*) Ordovicic.

Very small, usually not much exceeding 1/8 inch in width. Length greater than breadth. In these respects it resembles *Z. recurvirostris;* it differs from that species in the faintness of its

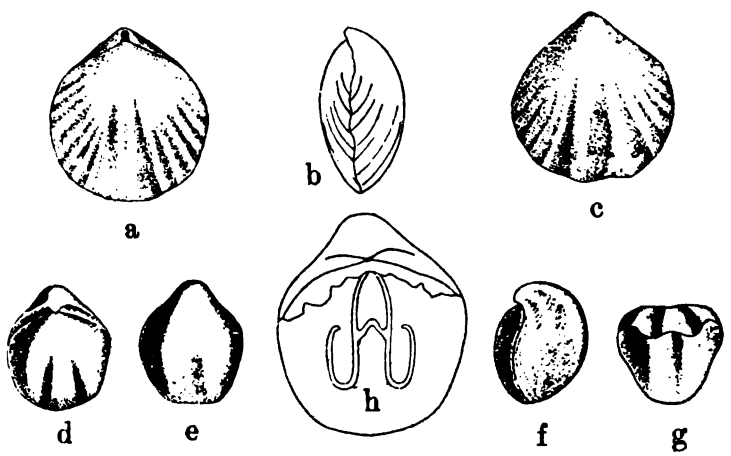


FIG. 386. *a–c*, *Zygospira nicoletti*, three views much enlarged; *d–h*, *Cyclospira bisulcata* four views enlarged × 2; and brachidium still further enlarged × 4. (After Winchell and Schuchert.)

plications and in the presence of a sinus on the pedicle valve and a fold on the brachial, being in these respects exactly opposite.

Trenton of Minnesota, Wisconsin and Missouri.

XCVIII. Cyclospira Hall and Clarke.

Subquadrate. Pedicle valve very convex with a prominent, incurved umbo and keeled posteriorly with a median sinus anteriorly. Brachial valve depressed, bearing a low median fold anteriorly; cardinal process small, supported by a low median septum. Brachidium very simple (Fig. 386, *h*). Surface smooth. Ordovicic–Siluric.

310. **C. bisulcata** (Emmons). (Fig. 386, *d–h.*) Ordovicic.

Small. Beak of pedicle valve defined on each side by two elevated ridges curving to the lateral margins of the valves.

Trenton of New York, Minnesota, Ontario, Manitoba.

XCIX. Atrypa Dalman.

Subcircular, strongly inequivalved. Hinge line short. Brachial valve very gibbous. Pedicle valve much less convex or nearly flat with a small, incurved beak and bearing a median sinus. Teeth large and widely separate. Muscular impressions strong. Spirals directed dorso-medially; jugum in extreme posterior portion. Surface radially plicate. Siluric – Mississippic.

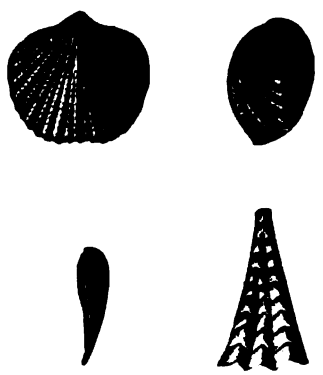


Fig. 387. *Atrypa nodostriata*, with striæ enlarged (Pal. N. Y. II.).

311. **A. nodostriata** Hall. (Fig. 387.) Siluric.

Valves subequal. Surface nodulose because of the lamellose growth lines.

Clinton and Niagaran of New York, Ohio, Kentucky, Wisconsin.

312. **A. marginalis** (Dalman). Siluric.

Length and breadth subequal. Beak of pedicle valve incurving over, but not covering that of the brachial valve. Both valves convex, the pedicle with a well-marked median sinus, bounded on each side by one or two stronger plications, and the brachial with a correspondingly well developed fold. Entire surface marked by radiating plications, which are crossed by concentric striæ which are often obsolete.

Niagaran of Kentucky, Tennessee, Ohio, Indiana, Illinois.

313. **A. rugosa** Hall. (Fig. 388.) Siluric.

Smaller than *A. nodostriata* and with equally convex valves. Surface marked by strong sinus and fold and concentric rugose lamellæ and by plications which are less rounded than in *A. nodostriata*.

Niagaran of New York, Kentucky, Indiana, Anticosti.

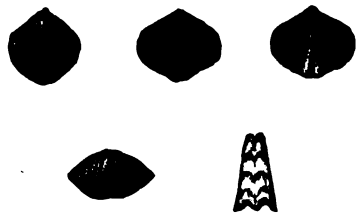


FIG. 388. *Atrypa rugosa*, with striæ enlarged (Pal. N. Y. II.).

314. **A. reticularis** (Linnæus). (Figs. 389, *a*; 389, *b*; 392, *a–c*.) Siluric and Devonic.

Pedicle valve nearly flat. Surface reticulated by the radiating and concentric striæ.

A characteristic Siluric and Devonic fossil throughout the world.

FIG. 389, *a*. *Atrypa reticularis* (Helderbergian) (Pal. N. Y. III.).

FIG. 389, *b*. *Atrypa reticularis* (Onondaga) (Pal. N. Y. IV.).

315. **A. impressa** Hall. (Fig. 390.) Devonic.

Differs from *A. reticularis* in being more gibbous, in the absence of a sinus in the pedicle valve and in the depression of the brachial valve toward the front. The striæ are finer and less conspicuous.

Schoharie of New York, Michigan.

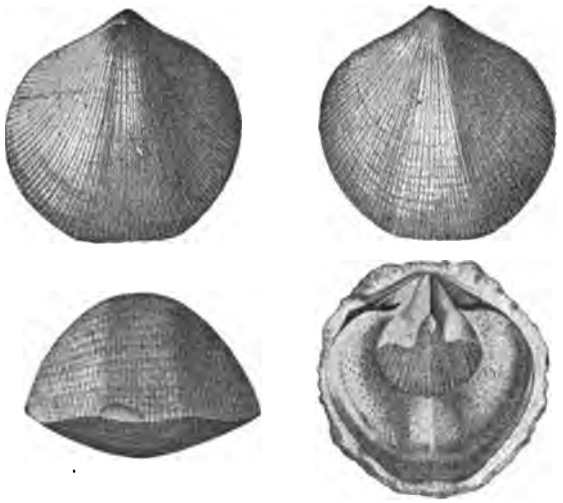


FIG. 390. *Atrypa impressa*, with interior of pedicle valve (Pal. N. Y. IV.).

316. **A. spinosa** Hall. (Figs. 391 and 392, *d.*) Devonic.

Hinge line but little less than the greatest width of the shell. Surface marked by strong, rounded, radiating costæ which bifurcate at unequal intervals and are crossed by strong concentric lamellæ; where these cross the costæ they are often produced into tubular spines. Differs from *A. reticularis* in the smaller number of costæ and in the longer and more nearly straight hinge line.

Onondaga–Chemung. Widely distributed throughout North America.

FIG. 391. *Atrypa spinosa*, a spineless individual (Pal. N. Y. IV.).

317. **A. hystrix** Hall. (Fig. 392, *e.*) Devonic.

Differs from *A. spinosa* in its fewer, coarse, rounded plication which are crossed by lamellose lines of growth and occasionally prolonged into few coarse spines.

Chemung of New York, Pennsylvania, Iowa and Wisconsin.

317*a*. **A. hystrix** var. **occidentalis** Hall. (Fig. 392, *f.*) Devonic.

Gibbous, with few coarse plications and strong lamellose growth lines but no spines.

Middle Devonic of Iowa and Rock Island, Ill.

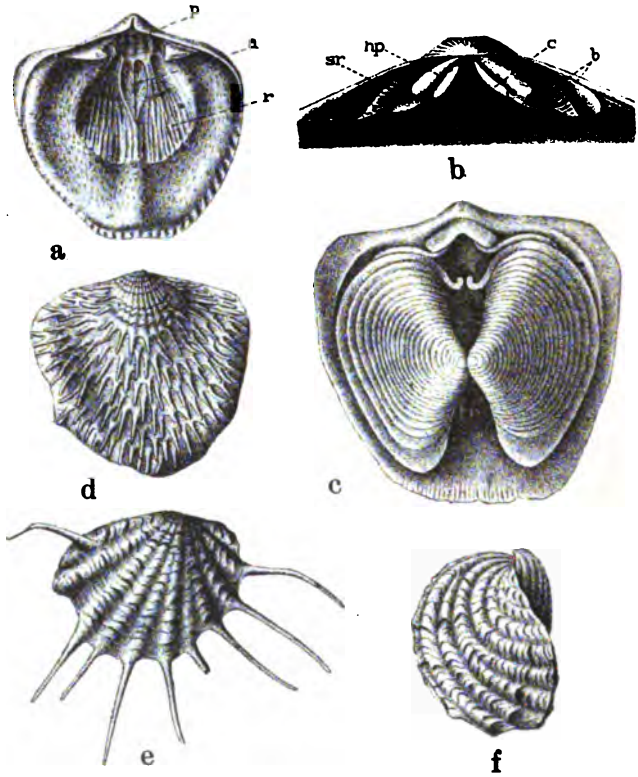


FIG. 392, *a–c*. *Atrypa reticularis*; *a*, interior of pedicle valve; *b*, cardinal portion of brachial valve; *c*, spirals showing after removal of brachial valve; *d*, *Atrypa spinosa*; *e*, *Atrypa hystrix*; *f*, *A. hystrix* var. *occidentalis*. *a*, adductor scars; *b*, dental sockets; *c*, crural bases; *hp*, hinge plate; *p*, pedicle scar; *r*, diductor scars; *sr*, crenulated ridge in sockets. (After Hall and Clarke.)

C. CYRTINA Davidson.

Small, spiriferoid, with very unequal valves. Differs from *Spirifer* in the semipyramidal form of the pedicle valve, the high, flat cardinal area and the narrow delthyrium closed by a convex pseudodeltidium which is usually perforated by a circular foramen. Shell structure punctate. The dental plates converge from the inner margins of the delthyrium and unite with the median septum, which reaches to the front, thus dividing the interior of the valve into two parts. Siluric–Mississippic.

A. Cardinal area of pedicle valve strongly arched. ..... *.
* Shell large, more than ½ inch wide..... 321. *C. alpenensis.*
* Shell small, less than ½ inch wide..... 320. *C. umbonata.*

B. Cardinal area of pedicle valve not strongly arched..... **.
** Beak incurved and pronounced..... 319. *C. hamiltonensis.*
** Beak inconspicuous. Cardinal area of pedicle valve almost vertical..... 1.
1. 2 to 5 plications on each side of fold and sinus..... 322. *C. acutirostris.*
1. 6 to 9 plications on each side of fold and sinus .....318. *C. dalmani.*

318. **C. dalmani** (Hall). Devonic.

Brachial valve semicircular; mesial fold flat; beak scarcely defined. Concentric lamellæ strong. Surface granulose-punctate.

Helderbergian of New York, Tennessee, Missouri and New Brunswick.

319. **C. hamiltonensis** Hall. (Fig. 393, *a–c.*) Devonic.

Beak slightly incurved and frequently distorted. Surface marked with 6–8 plications on each side of the well marked sinus and fold.

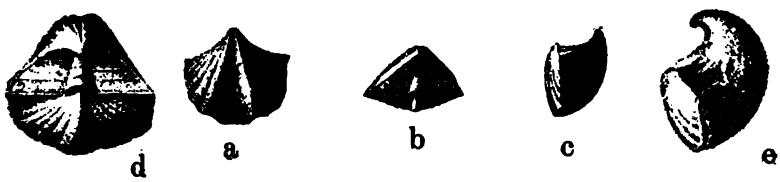


FIG. 393, *a–c. Cyrtina hamiltonensis; d–e, Cyrtina alpenensis* (Pal. N. Y. IV. and VIII.)

Onondaga, Hamilton and Portage; distributed throughout North America.

320. **C. umbonata** (Hall). Devonic.

Differs from *C. hamiltonensis* in its broader, arcuate and incurved umbo and beak and in that the 5 or 6 plications on each side of the mesial fold and sinus become obsolete before reaching the umbo, thus leaving that smooth or nearly so.

Hamilton of Illinois, Missouri, Iowa, Michigan.

321. **C. alpenensis** Hall and Clark. (Fig. 393, *d–e.*) Devonic.

Very similar to *C. umbonata* but is larger, with broad well defined plications and smooth median fold and sinus.

Hamilton of Michigan.

322. **C. acutirostris** (Shumard). Mississippic.

Small. Pedicle valve with very high and nearly vertical cardinal area. Brachial valve depressed-convex. Surface with two to five simple rounded plications on each side of the median fold and sinus; these are crossed by imbricating growth lines. Differs

from *C. umbonata* in its smaller size, wider hinge line and higher cardinal area.

Chouteau of Missouri.

CI. Cyrtia Dalman.

Semipyramidal shells with cardinal area vertical, that of the pedicle valve high and triangular. Delthyrium narrow, generally open. Otherwise like *Spirifer*. Siluric–Mississippic.

323. **C. alta** Hall. (Fig. 394.) Mississippic.

Semipyramidal with hinge line equaling the greatest width of shell. Pedicle valve very elevated; height to width about as three to five; sinus broad and rounded; cardinal area vertically striated. Brachial valve depressed-convex; cardinal area comparatively wide; surface marked with 25 to 30 low, rounded plications on each side of the median fold. Median fold and sinus faintly plicated.

FIG. 394. *Cyrtia alta* × ⅔ (Pal. N. Y. VIII.).

Waverly of Pennsylvania and Ohio.

CII. Spiriferina d'Orbigny.

Differs from *Cyrtina* in that the dental plates do not unite with the high median septum and in that the valves are less unequal in size. Shell substance punctate. (Devonic?) Mississippic–Jurassic.

324. **S. spinosa** (Norwood and Pratten). (Fig. 395.) Mississippic–Carbonic.

Of less than medium size, semioval. Brachial valve with prominent median fold. Pedicle valve slightly more convex than the opposite with strongly defined mesial sinus and slightly arched beak. Surface bearing four or five sub-angular or rounded plications on each side the fold and sinus, crossed by imbricating lamellæ of growth. Whole surface

FIG. 395. *Spiriferina spinosa*, a Mississippi Valley and a Nevada specimen. (After Walcott.)

finely punctate. Numerous, irregularly scattered, small spines present.

Kaskaskia of Kentucky, Indiana, Illinois. Upper Devonic? Mississippi and Carbonic of Nevada.

325. **S. kentuckiensis** (Shumard). (Fig. 396.) Upper Carbonic.

Small, varying in outline from subcircular to transversely produced. Differs from *S. spinosa* in its smaller size, pointed hinge extremities and greater number of plications (10–18).

Widely distributed in North America.

FIG. 396. *Spiriferina kentuckiensis* (Ind. Geol. Surv.).

CIII. SPIRIFER Sowerby.

Usually much wider than long, radially plicate or striate, crossed by concentric growth lines. Hinge line generally long and straight. Usually a median sinus present on pedicle valve and corresponding fold on brachial. Pedicle valve with moderately high area and open delthyrium, the margins of which are prolonged into stout, simple teeth supported by dental lamellæ. A calcareous brachidium in the form of a double spire, whose apexes are directed toward the cardinal extremities nearly fills the cavity of the shell. Jugum incomplete. Cardinal process low. A median septum at times present in one or both valves. Siluric–Carbonic.

A. Plications absent. Strong radiating striæ present..... 326. *S. radiatus*.
B. Plications present..... *.
* Plications covering entire surface..... †.
† Plications arranged in bundles or groups (fasciculate)..... ‡.
‡ Plications of nearly equal size..... 371. *S. striatus*.
‡ Plications of unequal size..... 372. *S. cameratus*.
† Plications not fasciculate..... ‡‡.
‡‡ Plications on fold and sinus nearly or quite like those on rest of shell..... 1.
1. Shell large, ventricose..... *a*.
a. Length exceeding breadth, very large..... 366. *S. grimesi*.
a. Breadth exceeding length..... 1′.
1′. Sinus prominent, much produced anteriorly..... *a*′.
a′. Beaks of both valves very prominent and arching. 346. *S. divaricatus*.
a′. Beak of pedicle valve much more prominent than that of brachial..... 368. *S. logani*.

1′. Sinus not produced anteriorly.....339. *S. arenosus.*
1. Shell of medium size and convexity..... *b.*
b. Cardinal area narrow..... 2′.
2′. Shell granulose..... 365. *S. marionensis*
2′. Shell not granulose..... *b′.*
b′. Hinge line extended..... 364. *S. centronatus.*
b′. Hinge line not extended..... 371. *S. striatus.*
b. Cardinal area moderately high..... 3′.
3′. Hinge line shorter than width of shell below.
373. *S. rockymontanus.*
3′. Hinge line forming greatest width of shell (usually to be recognized by peculiar internal mold).
361. *S. disjunctus.*
‡‡ Plications on fold and sinus extending only part way to the beak and hence differing from the other plications..... 2.
2. Plications angular..... 369. *S. leidyi.*
2. Plications rounded..... *c.*
c. Cardinal extremities rounded..... 4′.
4′. Plications few (6–10)..... 342. *S. grieri.*
4′. Plications many..... 363. *S. keokuk.*
c. Cardinal extremities angular..... 370. *S. increbescens.*
* Plications covering all the surface but fold and sinus..... ††.
†† Plications crossed by more or less conspicuous concentric lines, often producing a lamellose appearance..... ‡‡‡.
‡‡‡ Shell small, usually less than 1 inch wide..... 3.
3. Hinge line usually shorter than width of shell below..... *d.*
d. Furrow in median fold..... 331. *S. vanuxemi.*
d. No furrow in median fold..... 5′.
5′. Plications obsolescent..... 333. *S. corallinensis.*
5′. Plications well developed..... 330. *S. crispus.*
3. Hinge line extended..... *e.*
e. Plications 4–7 on each side fold and sinus... 329. *S. sulcatus.*
e. Plications many on each side fold and sinus..... 6′.
6′. Front broadly rounded..... 344. *S. varicosus.*
6′. Front narrowly rounded owing to the often mucronate hinge extremities..... 362. *S. subattenuatus.*
‡‡‡ Shell 1 inch or more wide..... 4.
4. Furrow in fold of brachial valve, hinge line extended.. ..... *f.*
f. Cardinal areas narrow..... 7′.
7′. Plications few and absent from the cardinal extremities.
357. *S. sculptilis.*
7′. Plications many..... 354. *S. mucronatus.*
f. Cardinal areas wide..... 8′.
8′. Beak prominent..... 356. *S. consobrinus.*
8′. Beak small..... 360. *S. mesicostalis.*
4. No furrow in fold of brachial valve..... *g.*
g. Hinge line shorter than width of shell below..... 9′.
9′. Beak of pedicle valve much elevated.
337. *S. concinnus.*
9′. Beak of pedicle valve not much elevated.
336. *S. cyclopterus.*

g. Hinge line extended ..... 10′.
10′. Cardinal area high..... *c*′.
c′. Plications few (2–5) on each side the mesial fold and sinus ..... *22*.
22. Plications broad, nearly equalling the mesial sinus in width.....343. *S. raricosta*.
22. Plications much narrower than mesial sinus. 335. *S. perlamellosus*.
c′. Plications many..... 338. *S. murchisoni*.
10′. Cardinal area linear.. ..... *d*′.
d′. Plications few (7 or 8 on each side the mesial fold and sinus) ..... 340. *S. duodenarius*.
d′. Plications many..... 354. *S. mucronatus*.
†† Plications marked by radiating striæ..... ‡‡‡‡.
‡‡‡‡ Cardinal area wide..... 5.
5. Plications few (3–4 on each side the mesial fold and sinus). 327. *S. eudora*.
5. Plications many..... *h*.
h. Shell small (¾ inch wide)..... 358. *S. tullius*.
h. Shell of medium size or large ..... 11′.
11′. Hinge line much extended. Shell often inequilateral. 351. *S. iowaensis*.
11′. Hinge line only slightly longer than width of shell below..... *e*′.
e′. Cardinal area subsemicircular.. 347. *S. euryteines*.
e′. Cardinal area subtriangular..... 348. *S. fornacula*.
‡‡‡‡ Cardinal area narrow..... 6.
6. Plications few (2 or 3 on each side mesial fold and sinus). 334. *S. macropleura*.
6. Plications many..... *i*.
i. Fold and sinus rapidly expanding. Shell large. 359. *S. mesistrialis*.
i. Fold and sinus slowly expanding..... 328. *S. niagarensis*.
†† Plications granulose, sometimes in radiating lines..... ..... 5‡.
5‡ Groove usually present in fold. Shell large..... 7.
7. Granules scattered, sinus deep, angular..... 350. *S. granulosus*.
7. Granules in lines, sinus rounded..... 349. *S. oweni*.
5‡ No groove in fold. Shell of medium size..... 355. *S. asper*.
†† Plications apparently smooth..... 6‡.
6‡ Shell very convex..... ..... 8.
8. Large (over 2 inches wide) ..... *j*.
j. Hinge line shorter than width of shell below. 367. *S. neglectus*.
j. Hinge line forming greatest width of shell..... 12′.
12′. Shell very ventricose with prominent triangular fold. 345. *S. acuminatus*.
12′. Shell moderately gibbous with low, rounded fold. *f*′.
f′. Plications numerous (30–35)..... 349. *S. oweni*.
f′. Plications few (10–16)..... 338. *S. murchisoni*.
8. Small (about ¾ inch wide), often with conspicuous concentric lines developed toward the front..... *k*.

k. Plications well developed..... 341. *S. gregarius.*
k. Plications nearly obsolete..... 332. *S. eriensis.*
6‡ Shell moderately convex with extended hinge line..... 9.
9. Proportion of length to breadth as 1–3..... 353. *S. angustus.*
9. Proportion of length to breadth as 1–2..... 352. *S. audaculus.*

326. **S. radiatus** Sowerby. (Figs. 397, 398.) Siluric.

Beak of pedicle valve strongly incurved; cardinal area moderately high. Median sinus broad and shallow; median fold flat-

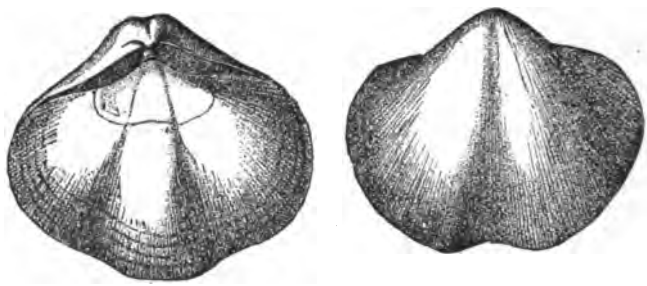


FIG. 397. *Spirifer radiatus* Smith. Western type. (After Hall.)

FIG. 398. *Spirifer radiatus.* New York type showing variation (Pal. N. Y., II.).

tened. No plications present but entire surface covered with fine, uniform, radiating striæ.

Clinton and Niagaran of New York, Tennessee, Kentucky, Indiana, Illinois, Wisconsin, Ontario, New Brunswick.

FIG. 399. *Spirifer eudora.* (After Hall.)

327. **S. eudora** Hall. (Fig. 399.) Siluric.

Of moderate size. Valves very gibbous. Hinge line less than width of shell below, with rounded extremities. Surface marked

by 3 to 4 strong, subangular plications on each side of the fold and sinus. Mesial sinus broad and deep. Entire surface covered with fine radiating striæ.

Niagaran of Kentucky, Indiana, Wisconsin.

328. **S. niagarensis** (Conrad). (Fig. 400.) Siluric.

Of moderate size, convex with nearly equal valves. Pedicle valve with strongly incurved beak. Surface covered with many fine depressed plications which become obsolete toward the extremities and sometimes appear quite flattened out. Fine, thread-like radiating striæ cover plications and interspaces alike.

FIG. 400. *Spirifer niagarensis* (Pal. N. Y., II.).

Niagaran of New York, Indiana.

329. **S. (Delthyris) sulcatus** Hisinger. (Fig. 401.) Siluric.

Gibbous. Valves unequal. Hinge line more or less extended, often mucronate. Plications 4 to 7 on each side of the mesial fold and sinus, crossed by strong imbricating lamellæ and longitudinallymarked by fine striæ.

Niagaran of New York, Ontario.

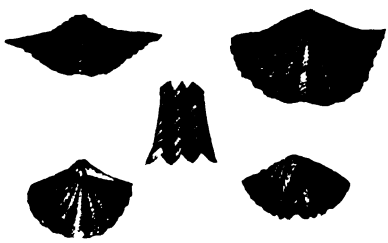


FIG. 401. *Spirifer (Delthyris) sulcatus*, with striæ enlarged (Pal. N. Y., II.).

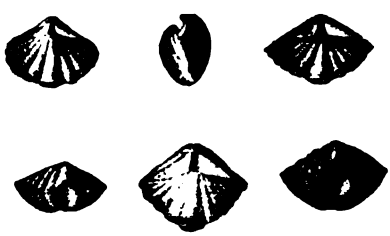


FIG. 402. *Spirifer crispus* (Pal. N. Y., II.).

330. **S. crispus** (Hisinger). (Fig. 402.) Siluric.

Small. Pedicle valve very convex with incurved beak and high cardinal area. Surface marked by broad plications, from 6 to 8 on each valve, strongest near fold and sinus and crossed by fine thread-like concentric striæ.

Niagaran of New York, Indiana, Ontario, Nova Scotia.

331. **S. vanuxemi** Hall. (Fig. 403.) Siluric.

Small, with rounded extremities. Surface marked by 2 to 4 broad plications on each side the mesial fold and sinus and by imbricating concentric growth lines. Differs from *S. crispus* in its narrower cardinal area, less elevated beak and les sgibbous form, and from *S. cyclopterus* in its smaller size and fewer plications, and from both in its scarcely distinguishable fold and sinus.

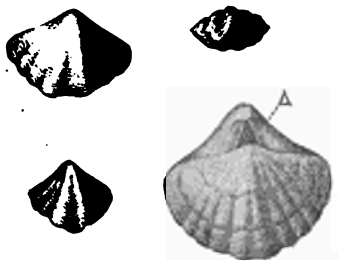


FIG. 403. *Spirifer vanuxemi.* Nat. size and enlarged (Pal. N. Y., VIII.).

Manlius of New York, Ohio, Michigan.

332. **S. eriensis** Grabau. (Fig. 404.) Siluric.

Pedicle valve very gibbous and almost square in outline. Cardinal area high. Sinus and fold sharply defined and angular, bounded by a few broad and nearly obsolete plications.

FIG. 404. *Spirifer eriensis.* (After Grabau.)

Cobleskill and Manlius of New York, etc.

333. **S. corallinensis** Grabau. (Fig. 405.) Siluric.

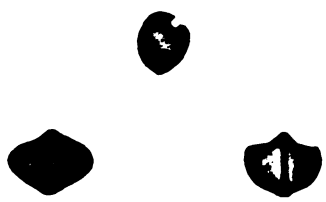


FIG. 405. *Spirifer corallinensis* (Pal. N. Y., III.).

Very small. Similar to *S. crispus* but differing in the uniformly obsolescent plications and the angular median sinus.

Cobleskill of New York, etc.

334. **S. macropleura** (Conrad). (Fig. 406.) Devonic.

Large, ventricose. Valves nearly equally convex. Pedicle valve with broad, deep sinus and three broad, rounded plications on each side. Brachial valve with broad, rounded fold and two rounded plications on each side. Whole surface covered with fine and close radiating striæ.

Helderbergian (New Scotland) of Maine, New York, Maryland, Tennessee.

335. **S. (Delthyris) perlamellosus** Hall. (Fig. 407.) Devonic.

Hinge line more or less extended. Pedicle valve arcuate with much extended and incurved beak. Sinus deep and profound,

FIG. 406. *Spirifer macropleura* (Pal. N. Y., VIII.).

produced anteriorly into a linguiform extension. Brachial valve convex in the middle with closely incurved beak. Surface marked by 4 to 6 strong plications on each side the median line and concentrically crossed by regular imbricating lamellæ which are strongly arched in passing over the plications, giving the surface a rough appearance.

Helderbergian of Maine, New York, Pennsylvania, Maryland, Tennessee, Missouri.

FIG. 407. *Spirifer* (*Delthyris*) *perlamellosus* (Pal. N. Y., VIII.). *D*, deltarium; *F*, foramen; *S*, median septum; *t*, teeth.

336. **S. cyclopterus** Hall. Devonic.

Semicircular. Hinge line usually shorter than width of shell below. Convexity of valves nearly equal. Surface marked by 7 or more rounded plications on each side of the mesial fold and sinus, concentrically crossed by fine, close, lamellose striæ.

Helderbergian and Oriskanian of Appalachian region (Maryland to New Brunswick and Gaspé).

337. **S. concinnus** Hall. (Fig. 408.) Devonic.

Semicircular. Hinge line usually shorter than the width of the shell below. Beak of pedicle valve elevated and incurved. Sinus and fold angular and sometimes marked by obscure plications toward the front. Plications rounded, 12–14 on each side of the median line and crossed by concentric striæ. Differs from *S.*

cyclopterus in the more elevated beak of the pedicle valve, the more numerous plications and in the angular character of sinus and fold with occasionally obscure plications.

Helderbergian (Becraft and Port Ewen) of New York.

FIG. 408. *Spirifer concinnus* (Pal. N. Y., VIII.).

338. **S. murchisoni** Castelnau. (Fig. 409.) Devonic.

Pedicle valve with elevated and incurved beak and high, concave cardinal area. Surface marked by 5 to 8 plications on each side of the prominent sinus and fold. Entire shell surface covered with fine, close concentric and radiating striæ. Internal mold of pedicle valve distinguished by a large, prominent striated process, indicating the form and dimensions of the muscular area. The mold is strongly papillose on each side of this area.

Oriskany of New York, Maryland, Ontario.

339. **S. arenosus** (Conrad). (Fig. 410.) Devonic.

Large, with valves of about equal convexity. Pedicle valve with broad and slightly incurved umbo. Mesial sinus very shallow

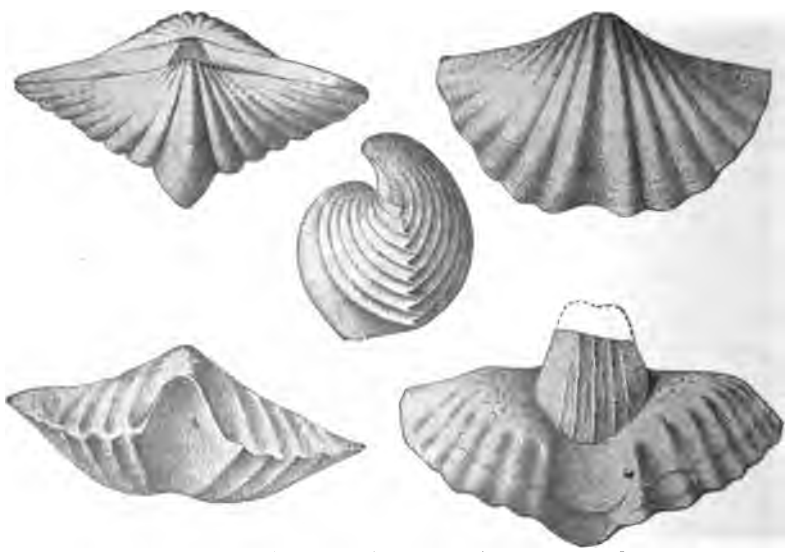


FIG. 409. *Spirifer murchisoni.* External views and internal mold (Pal. N. Y., III.)

and often producing merely a flattening of the surface. Mesial fold moderately elevated. Whole surface covered with 20 to 40

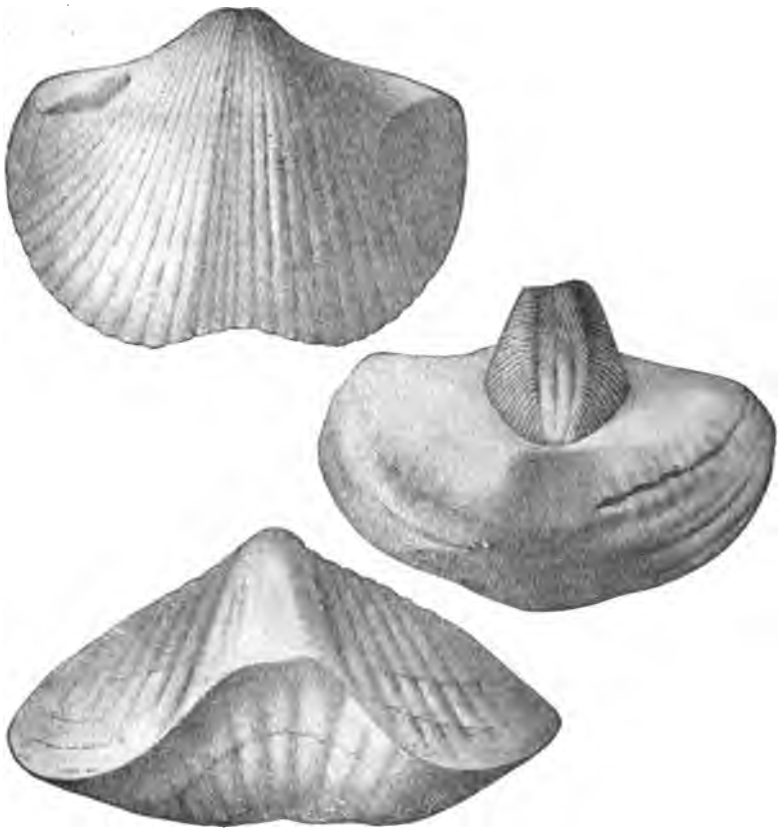


FIG. 410. *Spirifer arenosus.* External views and mold of interior (Pal. N. Y., III.).

low and even plications. Occurs largely as internal molds in the sandstones.

Oriskany and Onondaga (?) of New York, Pennsylvania, Maryland, Virginia, Ontario.

340. **S. duodenarius** (Hall). (Fig. 411.) Devonic.

Somewhat resembles *S. cyclopterus* but differs in its more extended hinge line which here forms the greatest width of the shell, in the narrow cardinal area which is here almost linear and in the less conspicuous striæ. Both valves are flattened at the cardinal extremities.

Onondaga of New York, Ohio, Kentucky, Indiana, Ontario.

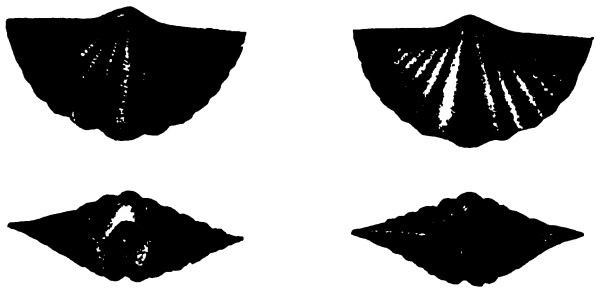


FIG. 411. *Spirifer duodenarius* (Pal. N. Y., IV.).

341. **S. gregarius** Clapp. (Fig. 412, *d–e.*) Devonic.

Small, ventricose. Cardinal extremities truncate or rounded. Pedicle valve regularly arcuate from beak to front with strongly incurved beak and high cardinal area; mesial sinus much produced in front. Surface marked with 6–10 strong ribs on each side of the median line. Entire surface covered with concentric striæ which toward the front become strong zigzag lines.

Onondaga of New York, Ohio, Kentucky, Indiana, Ontario.

342. **S. grieri** Hall. (Fig. 412, *a–c.*) Devonic.

Gibbous. Hinge lines usually shorter than the width of the shell below, with rounded extremities. Pedicle valve with promi-

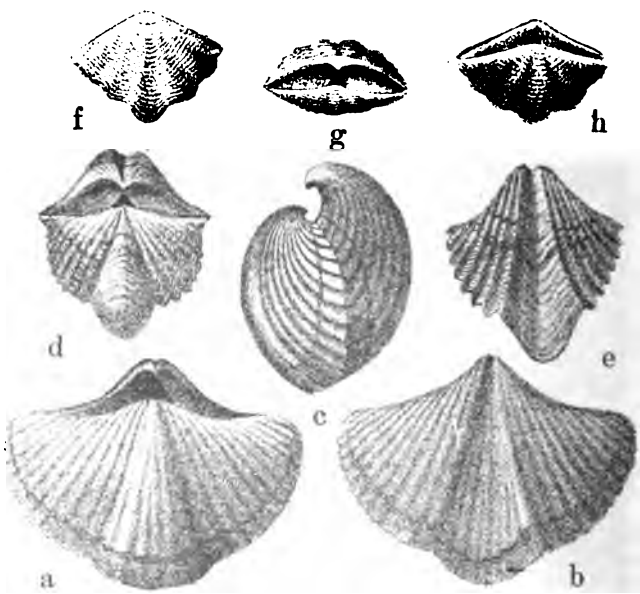


FIG. 412. *a–c, Spirifer grieri; d–e, Spirifer gregarius; f–h, Spirifer* (*Delthyris*) *arricosta.* (After Nettleroth.)

nent and much elevated beak, incurved over the high arcuate area. Sinus wide and deep. Brachial valve with small beak, slightly incurved over a nearly vertical, narrow cardinal area. Fold prominent and angular. Surface marked by 6 to 10 plications on each side the fold and sinus, while 3 or 4 smaller bifurcating plications are usually present on fold and sinus. Concentric lines present on well preserved specimens.

Onondaga of New York, Ohio and Kentucky.

343. **S. (Delthyris) raricosta** Conrad. (Fig. 412, *f–h.*) Devonic.

Gibbous, with rounded cardinal extremities. Pedicle valve with greatly elevated beak incurving over the high cardinal area. Brachial valve with small arching beak. Surface marked by 2 to 4 strong rounded ribs on each side the median line, crossed by concentric lamellose striæ and marked by fine and close radiating striæ.

Onondaga of Maine, New York, Ohio, Kentucky, Indiana, Nevada, Ontario, Quebec.

344. **S. varicosus** Hall. (Fig. 413, *a–c.*) Devonic.

Small, with length not exceeding half the width. Hinge extremities angular or mucronate. Pedicle valve much the more

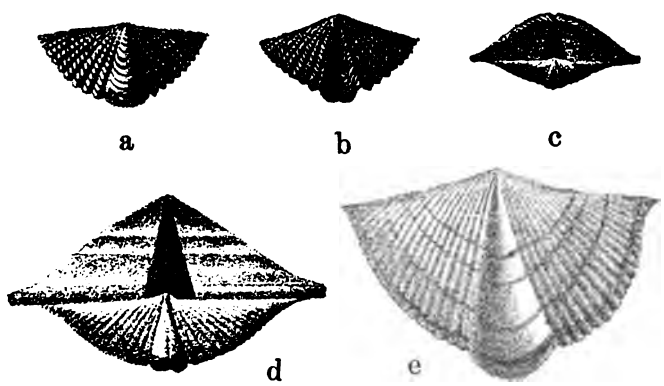


FIG. 413. *a–c, Spirifer varicosus; d–e, Spirifer eurytcines.* (After Nettleroth.)

convex with high cardinal area. Surface distinguished by the strong lamellose lines of growth which give it a varicose appearance.

Onondaga of New York, Ohio, Kentucky, Nevada, New Brunswick.

345. **S. acuminatus** (Conrad). (Fig. 414.) Devonic.

Large, ventricose. Pedicle valve with umbo incurved over the wide delthyrium. Surface distinguished by the very elevated and angular mesial fold and deep sinus, bounded by 16 to 20 plications.

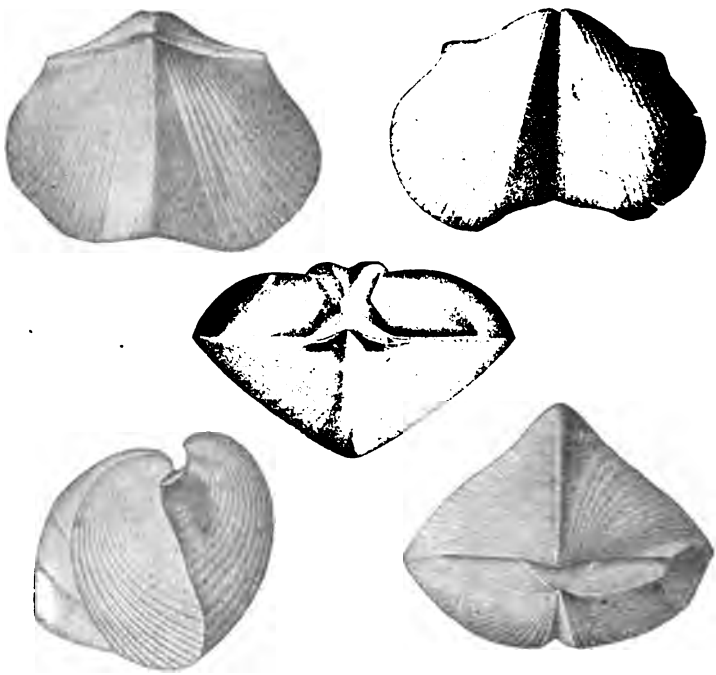


FIG. 414. *Spirifer acuminatus* external views and internal mold (Pal. N. Y., IV.).

Onondaga and Hamilton of New York, Ohio, Kentucky, Indiana.

346. **S. divaricatus** Hall. (Fig. 415.) Devonic.

Ventricose. Hinge line less than width of shell below, with rounded extremities. Cardinal areas wide. Beaks of both valves prominent and arching. Sinus and fold prominent and angular. Whole surface, including sinus and fold, covered with fine, rounded, bifurcating plications which are crossed by fine, zigzag, concentric striæ.

Onondaga and Hamilton of New York, Ohio, Kentucky and Port Colborne, Canada.

347. **S. euryteines** Owen. (Fig. 413, *d–e*.) Devonic.

Semielliptical. Cardinal area wide and slightly concave; beaks sometimes more than ½ inch apart. Fold and sinus bounded on

each side by 18 to 20 plications. Fold marked by a shallow sinus in the median line. Whole surface finely striated longitudinally. Hamilton of Iowa, Michigan, Nevada, Ontario.

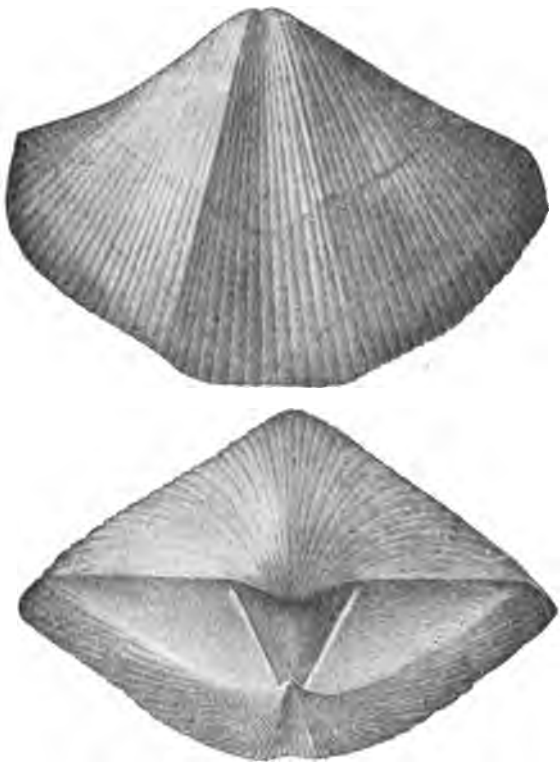


FIG. 415. *Spirifer divaricatus* (Pal. N. Y., IV.).

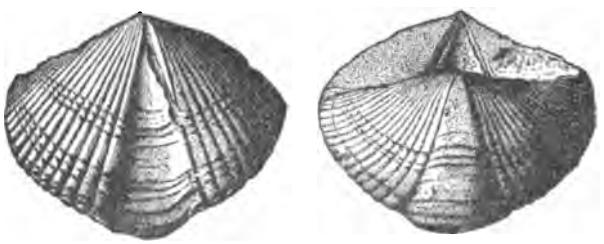


FIG. 416. *Spirifer fornacula* (Ind. Geol. Survey).

348. **S. fornacula** Hall. (Fig. 416.) Devonic.

Pedicle valve subpyramidal with the elevation equalling nearly half the width, curving abruptly to the front and lateral margins;

cardinal area extremely elevated, nearly flat above, with a large, open delthyrium. Brachial valve moderately convex. Sinus and fold bounded on each side by 16 to 20 plications. Length about ¾ inch,

Hamilton of Ohio, Kentucky, Indiana, Illinois, Wisconsin.

349. **S. oweni** Hall. Devonic.

Very similar to *S. granulosus* but differs in its smaller size, its subangular plications and median sinus, fewer plications (15 to 17 on each side the median fold and sinus), its subauriculate hinge extremities and especially in lacking the granulose surface so characteristic of the latter species.

Hamilton of Falls of Ohio region and Michigan.

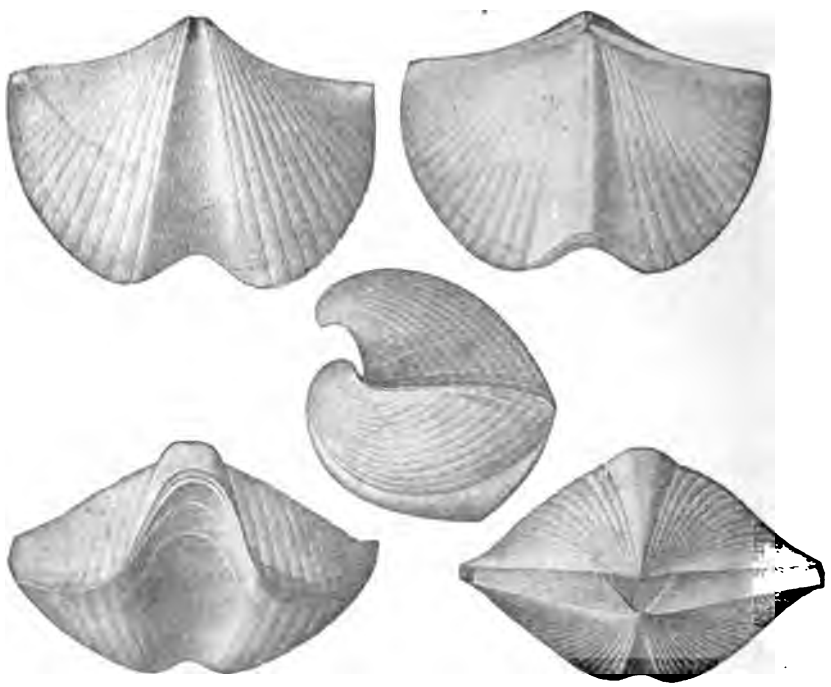


FIG. 417. *Spirifer granulosus* (Pal. N. Y., IV.).

350. **S. granulosus** (Conrad). (Fig. 417.) Devonic.

Large, robust and gibbous with high, curved cardinal area. Brachial valve with a prominent rounded fold, marked by a median depression. Plications low. Surface strongly granulose.

Hamilton. Widely distributed throughout eastern United States

351. **S. iowaensis** Owen. (Figs. 418, 419.) Middle Devonic.

Often inequilateral. Hinge line much extended. Valves often nearly equally convex. Beak of pedicle valve much elevated and slightly incurved. Whole surface, including fold and sinus and

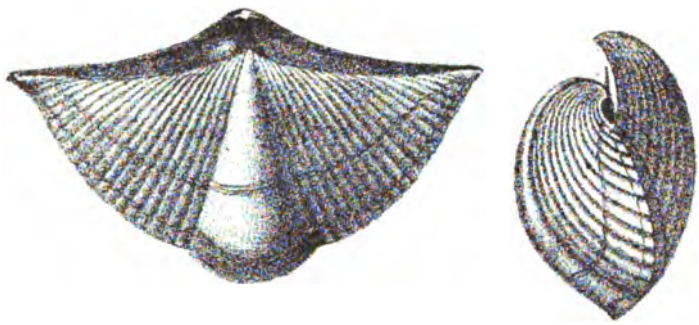


FIG. 418. *Spirifer iowaensis.* (After Nettleroth.)

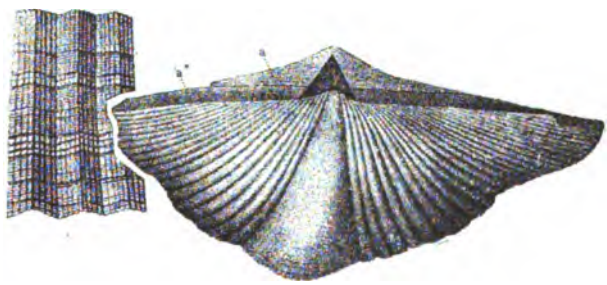


FIG. 419. *Spirifer iowaensis* (*S. pennata* Owen) × ⅔ with enlargement of surface. (After Hall.)

numerous plications, covered with slender, radiating striæ crossed by concentric growth lines.

Hamilton of Kentucky, Michigan, Indiana, Illinois, Wisconsin, Iowa, Arctic North America lat. 82° 42′.

352. **S. audaculus** (Conrad). (Fig 420, *a.*) Devonic.

Ventricose when old. Pedicle valve with high, concave cardinal area and incurved beak. Cardinal area of brachial valve linear. Mesial fold and sinus well marked. Surface covered with many concentric lines and plications marked with radiating striæ. Differs from *S. granulosus* in being smaller and in that the cardinal area of the brachial valve is linear.

Marcellus and Hamilton of New York, Kentucky, Indiana, Wisconsin.

353. **S. angustus** Hall. (Fig. 420, *b*.) Devonic

Valves with great lateral extension and pronounced inequality; the pedicle valve forming nearly the entire thickness of the shell. Brachial valve flat with narrow cardinal area and low mesial fold. Plications fine, from 48 to 56 on each valve.

Hamilton and Portage of New York, Wisconsin.

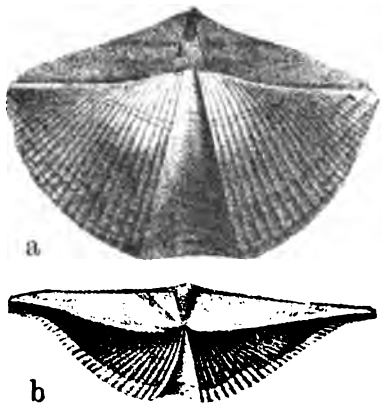


FIG. 420. *a*, *Spirifer audaculus*; *b*, *Spirifer angustus* (Pal. N. Y., IV.).

354. **S. mucronatus** Conrad. (Fig. 421.) Devonic.

Hinge line extended and often mucronate, giving the shell a width of from two to four times the length or greater. Cardinal areas low. Fold in brachial valve often flattened or grooved. Radiating plications numerous, crossed by lamellose lines of growth which are often crowded near the front. Often a plication in sinus.

Marcellus, Hamilton and Chemung of New York, Pennsylvania, Maryland, Virginia, Wisconsin, Ontario.

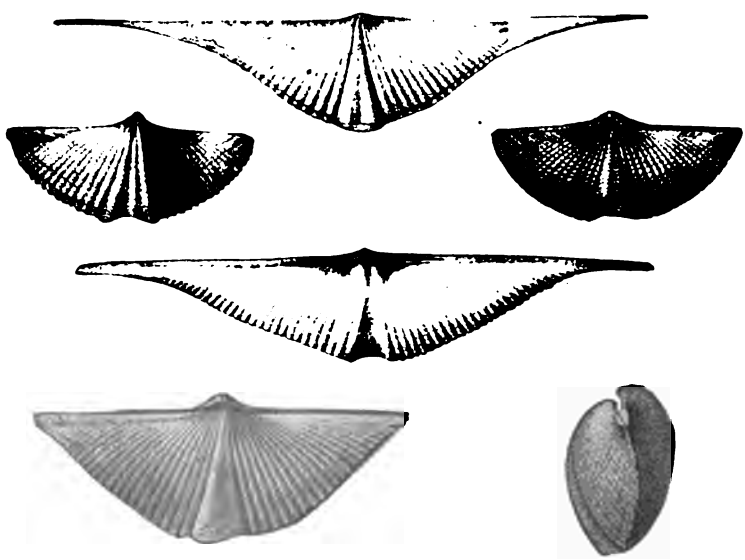


FIG. 421. *Spirifer mucronatus*, showing some of the varieties (Pal. N. Y., IV.).

355. **S. asper** Hall. Devonic.

Small, subpyramidal. Pedicle valve with high, flat cardinal area, narrow delthyrium and broad, shallow sinus, rapidly narrowing toward the beak. Fold low and rounded. Plications fine and low. Whole surface granulose.

Hamilton of New York, Illinois, Wisconsin, Iowa.

356. **S. (Delthyris) consobrinus** d'Orbigny. (Fig. 422, *a–b.*) Devonic.

Gibbous with pedicle valve the more convex and arcuate from beak to front. Cardinal area elevated and concave. Sinus deep and wide. Brachial valve with an abruptly elevated mesial fold usually marked by a depression. Surface marked by 8 to 12 angular radial plications crossed by concentric lamellæ.

Hamilton of New York, Kentucky, Ohio, Wisconsin.

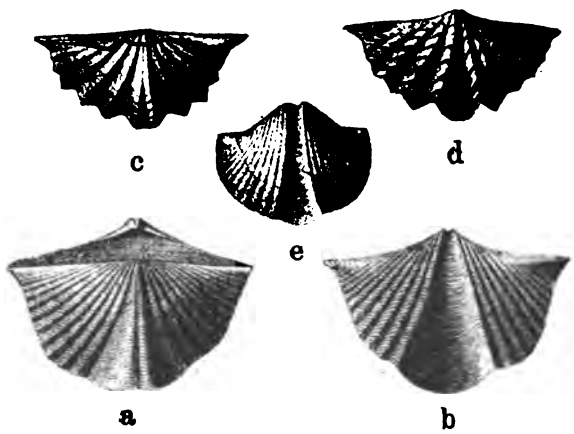


FIG. 422. *a–b, Spirifer* (*Delthyris*) *consobrinus; c–d, S.* (*Delthyris*) *sculptilis; e, Spirifer tullius* (Pal. N. Y., IV.).

357. **S. (Delthyris) sculptilis** Hall. (Fig. 422, *c–d.*) Devonic.

Gibbous. Hinge line prolonged into mucronate extensions. Length of shell about half the width on the hinge line. Surface strongly marked by 3 to 5 strong plications on each side of the fold and sinus, leaving a somewhat wide space at the cardinal extremities marked only by the concentric striæ which cross the whole shell as strong imbricating lamellæ.

Hamilton of New York, Pennsylvania, Kentucky, Indiana, Ontario.

358. **S. tullius** Hall. (Fig. 422, *e.*) Devonic.

Small, gibbous, subelliptical. Pedicle valve with high cardinal area. Plications rather flattened and low. Whole surface covered with fine, uniform, radiating striæ and faint concentric ones. Sinus and fold well defined, extending quite to the beak.

Upper Hamilton of New York, Northwest Territory.

359. **S. mesistrialis** Hall. (Fig. 423.) Devonic.

Large. Cardinal angles rounded or mucronate. Sinus and fold broad, rapidly becoming expanded toward the front. Plications 16

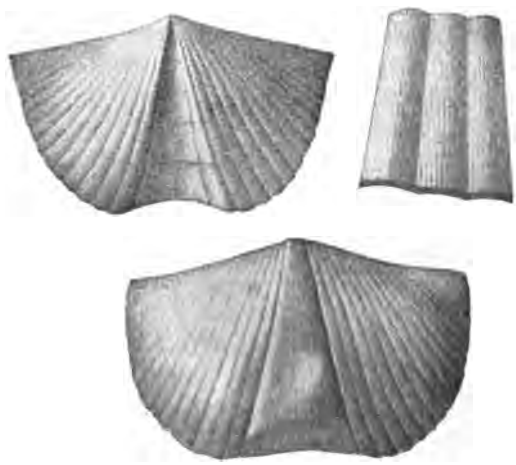


Fig. 423. *Spirifer mesistrialis* with enlargement of striæ (Pal. N. Y. IV.).

to 20. The whole shell, including sinus and fold, conspicuously marked by fine radiating striæ.

Portage and Chemung of New York.

360. **S.** (**Delthyris**) **mesicostalis** Hall. (Fig. 424, *a.*) Devonic.

Cardinal extremities usually extended. Pedicle valve with small beak, the upper part only being abruptly curved over the moderately high cardinal area. Sinus angular with a well defined fold in the bottom. Brachial valve with linear cardinal area and mesial fold marked by a deep groove in the middle. Differs from *S. mucronatus* in the duplication of the mesial fold and in the long septum extending from the beak nearly to the front of the muscular impression.

Ithaca and Chemung of New York.

361. **S. disjunctus** Sowerby. (Fig. 424, *b–d.*) Devonic.

Very variable in shape from semicircular to attenuate winged. Pedicle valve but slightly incurved at beak, its internal mold gives a triangular area in part marked by the muscular impression dis-

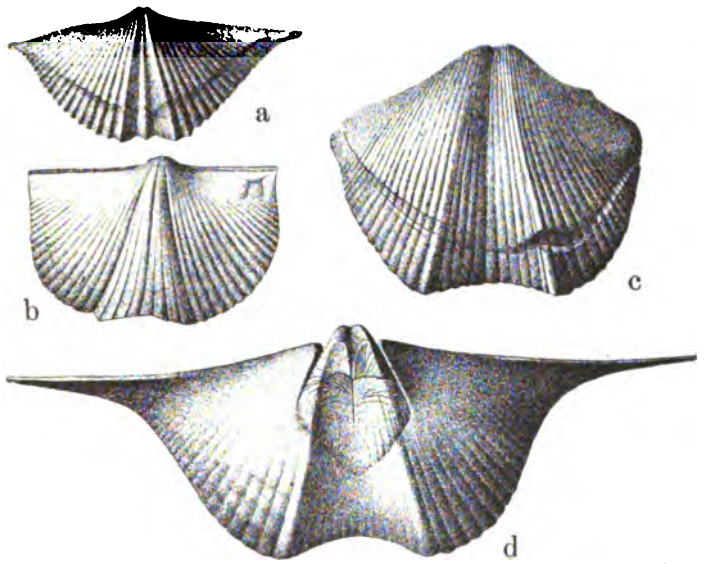


FIG. 424. *a*, *Spirifer mesicostalis*, *b-d*. *Spirifer disjunctus* showing variation of form *d*. internal mold (Pal. N. Y.).

joined from the sides of the shell by narrow fissures formerly occupied by the dental lamellæ. Surface of both valves, including sinus and fold covered with very low, even plications. Sinus and fold are sharply defined from the rest of the shell.

Chemung; throughout North America. Also Europe, etc.

362. **S. subattenuatus** Hall. Devonic–Mississippic.

Small with hinge line often extending into mucronate points. Mesial sinus deep and subangular. Surface with 8 to 12 strong plications on each side the median line, crossed by sharp concentric laminæ. Differs from *S. mucronatus* in its smaller size, more elevated plications and stronger imbricating lamellæ.

Chemung of New York and Marshall of Michigan; equivalent horizons of Illinois, Iowa, Northwest Territory.

363. **S. keokuk** Hall. (Fig. 425, *a–b.*) Mississippic.

Gibbous. Valves nearly equal in convexity. Pedicle valve with

very prominent and strongly incurved beak. Plicatious many, covering the entire shell and marked by fine radiating and concentric striæ.

Keokuk of Ohio, Illinois, Iowa, Utah.

364. **S. centronatus** A. Winchell. (Fig. 425, *c*.) Mississippic.

Of medium size, broadest at hinge line often mucronate. Valves moderately convex. Beak of pedicle valve strongly elevated and incurved. Surface with 34 to 42 small plications of which 4 to 6 mark sinus and fold.

Waverly of Ohio, South Dakota, Utah, Wyoming, Nevada.

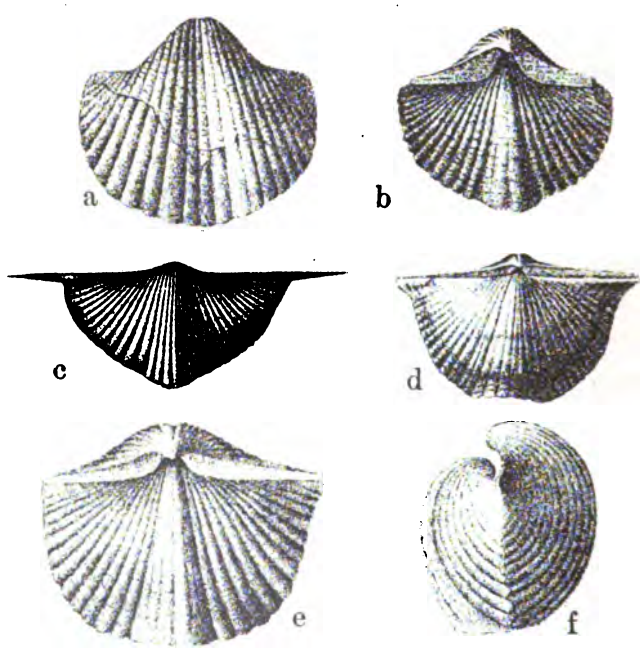


FIG. 425, *a-b*. *Spirifer keokuk*. *c*, *Spirifer centronatus*. *d*, *Spirifer marionensis*. *e-f*, *Spirifer increbescens*. (After Hall.) Nettelroth and Pal. Ohio.

365. **S. marionensis** Shumard. (Fig. 425, *d*.) Mississippic.

Nearly semicircular with hinge line extended in mucronate points. Valves nearly equally convex. Fold and sinus marked by 2 or 3 dichotomizing plications. Cardinal areas narrow. Surface covered with many plications which irregularly bifurcate. Granulose.

Chouteau of Ohio, Missouri.

366. **S. grimesi** Hall. (Fig. 426.) Mississippic.

Very large and gibbous. Mesial fold and sinus broad and ill defined. Entire surface covered with very depressed, irregularly bifurcating plications.

Kinderhook and Burlington of Missouri, Illinois, Iowa, Arctic North America lat. 82° 43′.

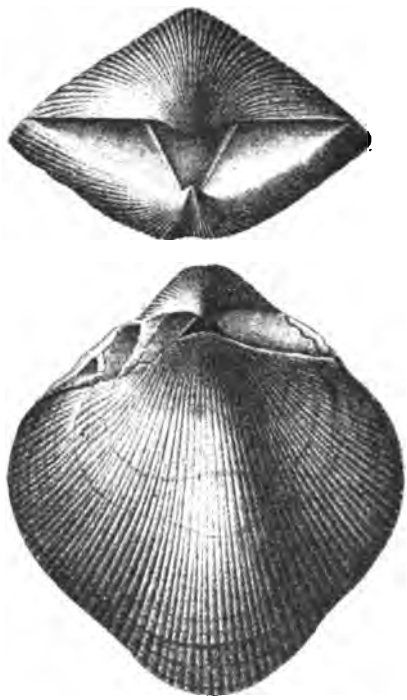


FIG. 426. *Spirifer grimesi*, × ⅔. (After Hall.)

367. **S. neglectus** Hall. Mississippic.

Hinge line less than width of shell below and rounded at the extremities. Pedicle valve a little more convex than the brachial with strongly arched beak and cardinal area. Mesial fold and sinus small at beak but increasing very rapidly in width toward the front. Surface maked by about 6 plications on each side the fold and sinus.

Keokuk of Illinois, Iowa, Nevada.

368. **S. logani** Hall. (Fig. 427.) Mississippic.

Very large gibbous. Length and width as three to four. Fold in brachial valve very prominent and elevated. Sinus in pedicle valve broad and undefined, produced anteriorly. Surface, including fold and sinus, covered with small, nearly equal plications.

Keokuk of Illinois, Tennessee and Missouri.

369. **S. leidyi** Norwood and Pratten. (Fig. 428.) Mississippic.

Small. Pedicle valve gibbous; brachial valve depressed-convex. Mesial fold bearing a well defined depression in the center, reaching half way to the beak. Surface marked by 7 or 8 plications and by longitudinal and concentric striæ.

St. Louis of Kentucky, Indiana, Illinois, Utah, Nevada.

370. **S. increbescens** Hall. (Fig. 425, *e–f.*) Mississippic.

Gibbous. Hinge line always as long as the greatest width of the shell and terminating in more or less extended mucronate tips which are often unequal on the two sides of the shell. Whole surface covered with plications, those on the fold and sinus extending only part way to the umbo and narrower than those on the sides of the shell.

Kaskaskia of Illinois and Kentucky.

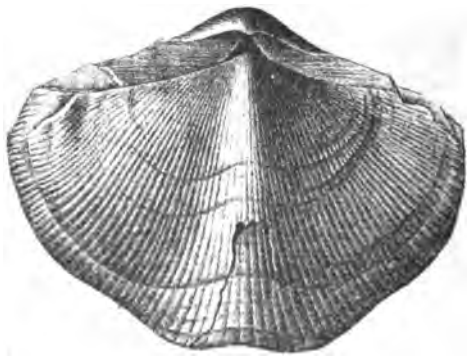


FIG. 427. *Spirifer logani*, × ⅔. (After Hall.)

FIG. 428. *Spirifer leidyi.* (After Whitfield.)

371. **S. striatus** (Martin). Carbonic.

Pedicle valve the more convex and marked by a broad, ill defined mesial depression; beak small, pointed and closely incurved. Entire surface of valves marked by plications which are nearly uniform in size with little tendency to become fasciculate as in *S. cameratus.*

Utah, Nevada, New Mexico, Nova Scotia.

372. **S. cameratus** Morton. (Fig. 429.) Carbonic.

Of medium size or large, broadest at hinge line, with cardinal extremities often pointed. Pedicle valve with concave cardinal area of moderate height. Mesial fold and sinus as well as the rest of the shell covered with many striæ of unequal size, usually arranged in bundles (fasciculate).

Throughout North America.

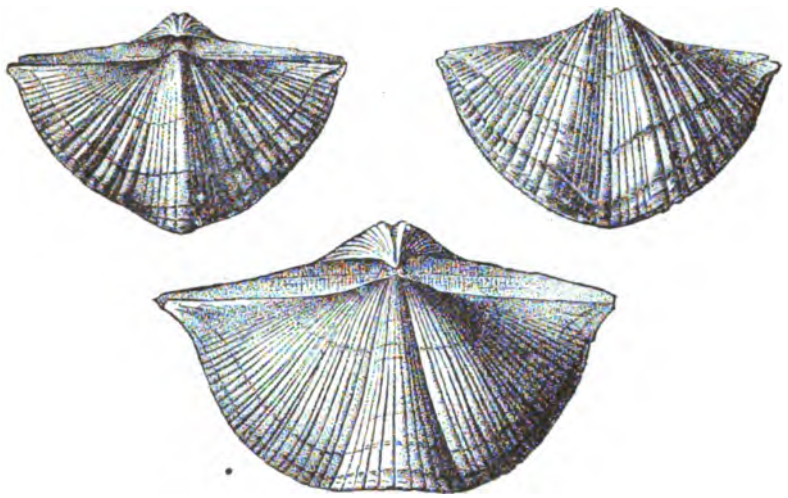


FIG. 429. *Spirifer cameratus.* Two individuals showing variation (Ind. Geol. Survey).

373. **S. rockymontanus** Marcou. (Fig. 430.) Carbonic.

Hinge line a trifle shorter than the width of the shell below. Pedicle valve with moderately well defined sinus and concave cardinal area with beak strongly incurved over it. Whole surface marked by 24 to34 quite uniform plications.

Widely distributed through North America.

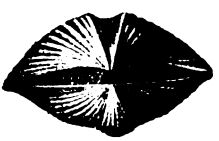


FIG. 430. *Spirifer rockymontanus.* (After Hall.)

CIV. RETICULARIA McCoy.

Like *Spirifer* but with hinge line less than the greatest diameter of the shell. Radial plications obsolescent or absent. Surface bearing rows of fine spines placed on concentric striations or ridges. Siluric–Carbonic.

A. Conspicuously spine-bearing..... *.
  * Small, diameter about $\frac{3}{5}$ inch..... 377. *R. cooperensis.*
  * Of medium size, diameter exceeding 1 inch ..... 1.
    1. Width much exceeding length..... *a.*
      a. No plications on surface..... 378. *R. pseudolineata.*
      a. Low plications present (3–9 on each side the median line). 374. *R. fimbriata.*
    1. Width and length about equal..... 379. *R. setigera.*

B. Apparently spineless ..... **.
** Surface usually smooth. Shell large..... 376. *R. lævis.*
** Surface smooth; shell of medium size..... 375. *R. nevadaensis.*
** Surface marked by crenulate concentric lines. Small..... 380. *R. perplexa.*

374. **R. fimbriata** (Conrad). (Fig. 431, *a–b.*) Devonic.
Gibbous, with rounded cardinal extremities. Pedicle valve with

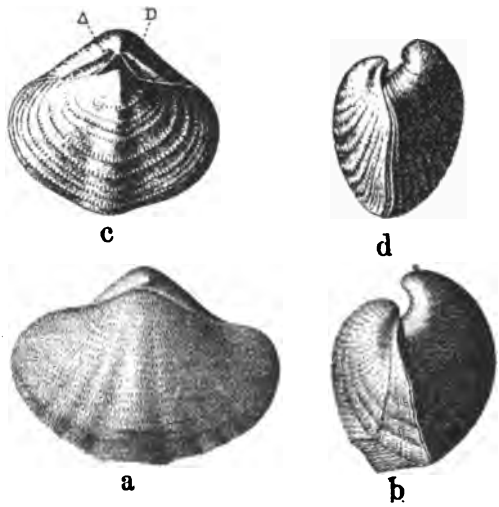


FIG. 431, *a–b. Reticularia fimbriata*; *c–d, Reticularia setigera.* (After Hall.)

small beak incurved over the high and concave cardinal area which is striated vertically. Brachial valve with small and slightly arching beak. Surface marked by 3 to 9 low plications on each side the mesial fold and sinus, crossed by imbricating lamellose striæ; these striæ are studded with elongate nodes or tubules.

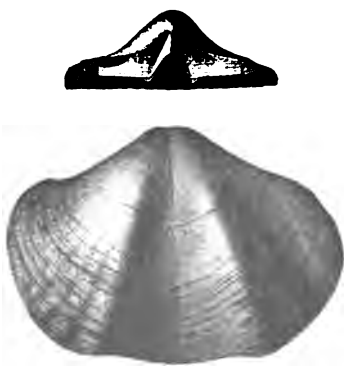


FIG. 432. *Reticularia lævis*, × ⅔ (Pal. N. Y. IV.).

Oriskany – Ithaca. Widely distributed through North America.

375. **R. nevadaensis** (Walcott). (Fig. 435, *c.*) Upper Devonic.
Less transverse than preceding fold and sinus often more angular, no plications, surface appearing smooth.

Devonic limestones of Nevada.

376. **R. lævis** (Hall). (Fig. 432.) Upper Devonic.

Ventricose with rounded cardinal extremities. Length to breadth as 2 to 3 or as 3 to 4. Pedicle valve with abruptly attenuate and arching beak; foramen partially closed by an arching and very convex pseudo-deltidium. Sinus either shallow or deep. Brachial valve only moderately convex with an undefined mesial fold. Surface usually smooth or marked only by concentric growth lines. In old age at times there appear a few obscure radiating folds.

Portage of New York.

377. **R. cooperensis** (Swallow). Mississippic.

Small (length and breadth about $\frac{2}{5}$ inch), gibbous, with greatest breadth a little above the middle. Front subtruncate or slightly sinuous in the middle. Pedicle valve much the more gibbous with a

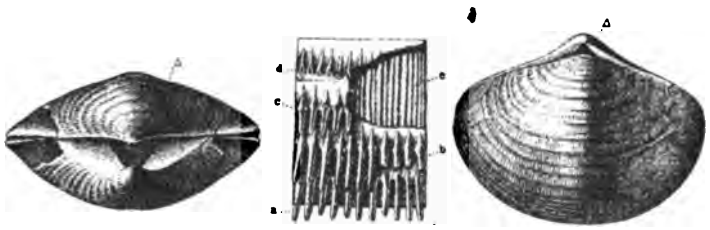


FIG. 433. *Reticularia pseudolineata*, × $\frac{2}{3}$, with enlargement of part of surface. (After Hall.)

shallow mesial sinus; beak prominent and incurved beyond the hinge line; foramen wide and triangular. Brachial valve depressed-convex with low mesial fold. Surface covered with 2 to 4 very obscure and depressed radial plications on each side the fold and sinus.

Kinderhook of Tennessee, Indiana, Missouri, Iowa.

378. **R. pseudolineata** (Hall). (Fig. 433.) Mississippic

Width greatly exceeding length. Pedicle valve with shallow mesial sinus and prominent incurved beak. Surface marked by more or less regular concentric lamellose folds or wrinkles and radiating striæ extended into long spines from the edges of the folds.

Burlington–Keokuk of Missouri, Indiana, Illinois?, Iowa.

379. **R. setigera** (Hall). (Fig. 431, *c–d.*) Mississippic.

Much like *R. pseudolineata*, but differs in that here the length and breadth are more nearly equal and the beak is higher and narrower.

Kaskaskia of Kentucky, Illinois, Utah.

380. **R. perplexa** (McChesney). (Fig. 434.) Carbonic.

Small; moderately gibbous. Beaks prominent and incurved. Pedicle valve without pronounced mesial sinus, but slightly flattened or with a shallow though sharp depression anteriorly. Surface marked by numerous very faint radiating lines and somewhat stronger concentric lines, the latter finely crenulate, marking the bases of hair-like spines not preserved.

Widely distributed in North America.

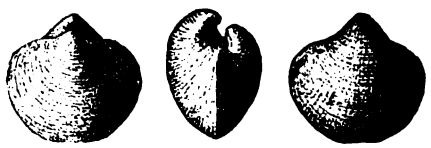


FIG. 434. *Reticularia perplexa* (Ind. Geol. Survey).

CV. MARTINIA McCoy.

Like *Spirifer*, but with hinge line shorter than the greatest width of the shell, and cardinal angles obtusely rounded. Surface smooth except for the concentric striæ. Muscular impressions narrow and faint. Devonic–Carbonic.

381. **M. maia** (Billings). (Fig. 435, *a–b.*) Devonic.

Longitudinally ovate. Cardinal area narrow and sometimes hidden by the beak. Brachial valve with rounded mesial fold.

a c b

FIG. 435. *a–b, Martinia maia; c, Reticularia nevadaensis.* (After Walcott).

Pedicle valve more convex than the brachial, with a large incurved beak.

Onondaga of Ohio, Nevada, Ontario.

382. **M. glabra** (Martin). Carbonic.

Subcircular to ovate. Pedicle valve with a moderately developed mesial sinus, high cardinal area and incurved beak. In

brachial valve the mesial fold merges into the rest of the surface. Nova Scotia.

CVI. SYRINGOTHYRIS A. Winchell.

Spiriferoid, usually large. Pedicle valve with high, erect cardinal area; that of brachial valve low. Dental lamellæ strong, surrounding the broad, muscular impressions. A tube (syrinx), open along its inner margin, extends from the apex of the pedicle valve between the dental lamellæ and the deltidium (when present), for

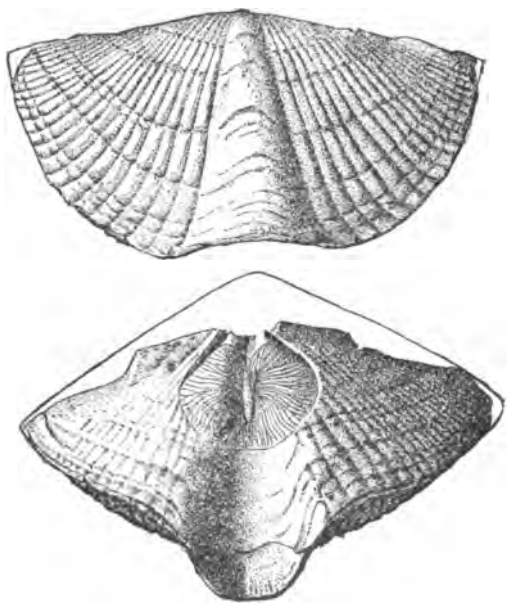


FIG. 436. *Syringothyris texta.* (Ind. Geol. Survey.)

about half the length of the valve. It is formed by the deposition of accretions to the margins of the delthyrium. Shell punctate. Entire surface marked by minute, elongated pits, giving (under a lens) the appearance of twilled cloth. Mississippic.

383. **S. carteri** (Hall). Mississippic.

Length usually more than half the width or subequal. Cardinal extremities nearly rectangular. Pedicle valve the more convex; prominent at the umbo.

Waverly, Burlington and Chouteau of Ohio, Missouri, Iowa, Montana, Nevada.

384. **S. texta** (Hall). (Figs. 436–437.) Mississippic.

Large, ⅓ to ½ as long as broad. Height often greater than length. Hinge line forming the greatest width of the shell. Pedicle valve the more convex, very prominent at umbo; mesial sinus deep, rapidly increasing in width from beak to front where it occupies about one fourth of the anterior margin; beak angular; cardinal area high and nearly straight. Brachial valve most convex near the front. Surface marked by about 20 simple plications on each side the median line, crossed by concentric growth lines. Much heavier, wider and more robust than *S. carteri*.

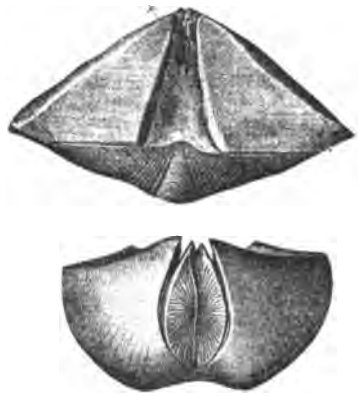


FIG. 437. *Syringothyris texta*, × ⅔ (Ohio Pal.).

Waverly–Keokuk of Kentucky, Indiana, Ohio, Iowa, Illinois.

CVII. AMBOCŒLIA Hall.

Small. *Spirifer*-like. Pedicle valve greatly elevated, with a conspicuous, strongly incurved umbo; cardinal area arched and delthyrium open. Brachial valve with long, narrow cardinal process, crural plates long, parallel, erect; four well defined adductor scars present near the anterior margin. Devonic–Carbonic.

385. **A. præumbona** Hall. (Fig. 438, *a–b*.) Devonic.

Hinge line less than the greatest width of shell with rounded cardinal extremities. Pedicle valve very ventricose, bearing a shallow impressed median line. Brachial valve slightly convex. Surface marked only by concentric striæ which are sometimes crowded into imbricating folds.

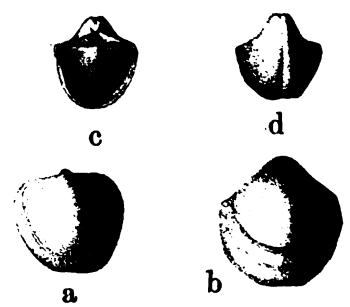


FIG. 438. *a–b, Ambocœlia præumbona; c–d, Ambocœlia umbonata* (Pal. N. Y. IV.).

Hamilton of New York.

386. **A. umbonata** (Conrad). (Fig 438, *c–d.*) Devonic.

Differs from *A. præumbona* in its smaller size, distinct though narrow mesial sinus and proportionally longer hinge line which here usually forms the greatest width of the shell.

Marcellus–Chemung of New York, Pennsylvania, Kentucky, Indiana.

387. **A. nana** Grabau. (Fig. 439.) Devonic.

Small, transverse. Brachial valve convex, bearing a shallow mesial depression. Surface covered with numerous elongated pits.

Marcellus and Hamilton of New York.

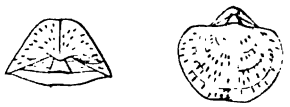


FIG. 439. *Ambocœlia nana.* (After Grabau), enlarged, × 2.

FIG. 440. *Ambocœlia planoconvexa* × 2 (Ind.Geol. Survey.)

388. **A. planoconvexa** (Shumard), (Fig. 440.) Carbonic.

Breadth and length about equal. Brachial valve circular except for its truncation by the hinge line and nearly flat, with minute beak and narrow cardinal area. Pedicle valve convex; mesial sinus represented by a slight flattening in front. Surface seen to be finely granulose under a lens.

Widely distributed throughout North America. Conemaugh of Pennsylvania, Ohio and West Virginia.

CVIII. METAPLASIA Hall and Clarke.

Spiriferoid but differing from *Spirifer* in the reversal of sinus and fold, *i. e.*, the pedicle valve bears the median fold and the brachial the median sinus. The teeth are supported by lamellæ, the muscular impressions of the pedicle valve are separated by a short, thick septum and the cardinal process is strong and bilobed. Devonic.

389. **M. pyxidata** Hall. Devonic.

Small. Pedicle valve with a strong, broad elevation, furrowed by a narrow sinus down the middle. Brachial valve flat and marked by a broad depression in the center of which is a narrow elevation. Surface when perfectly preserved both concentrically and longitudinally striated.

Oriskany of New York, Maryland, Ontario.

CIX. Rhynchospira Hall.

Rostrate, subtriangular. Hinge line short and curved. Umbo of pedicle valve incurved; apex truncated by circular foramen. Deltidial plates coalesced; teeth small, not supported by dental plates. In brachial valve hinge plate produced anteriorly into two flat lobes. Median septum short and sometimes obscure. Surface bearing simple radial plications. Shell punctate. Siluric–Mississippic.

390. **R. formosa** Hall. Devonic.

Pedicle valve tapering toward the beak, which is prominent and arched. Brachial valve gibbous, with closely incurved beak. Surface marked by 18 to 23 simple plications, two or three of which are smaller and slightly depressed on the middle of each valve; these are crossed by fine concentric growth lines which become strongly lamellose anteriorly.

Helderbergian of Maine, New York, Ohio.

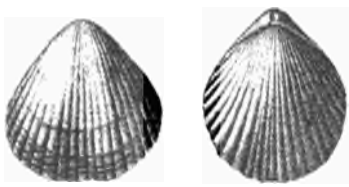


Fig. 441. *Homœospira evax* × 2. (After Hall.)

Fig. 442. *Hustedia mormoni* (Ind. Geol. Survey).

CX. Homœospira Hall and Clarke.

Like *Rhynchospira* but in the brachial valve the crural plates are separated by a linear cardinal process and a high median septum is present while the deltidial plates frequently remain uncoalesced; shell punctate. Siluric.

391. **H. (Retzia) evax** Hall. (Fig. 441.) Siluric.

Ovate, usually longer than wide, gibbous. Both valves sometimes bearing a shallow sinus anteriorly. Pedicle valve the deeper with greatly elevated and incurved umbo. Foramen circular. Surface marked by 16 to 28 radiating plications crossed by fine striæ and imbricating, lamellose growth lines.

Niagaran of Tennessee, Indiana.

CXI. HUSTEDIA Hall and Clarke.

Differs externally from *Rhynchospira* only in its much coarser plications. Internally it differs in the structure of the hinge plate and in the presence of a split and weak tube attached by one side to the deltidial plates. Carbonic.

392. **H. mormoni** (Marcou). (Fig. 442.) Carbonic.

Small. Both valves more or less gibbous. Umbo prominent and arched. Surface marked by 14 to 17 simple radiating ribs.

Widely distributed throughout Central and Western United States.

CXII. TREMATOSPIRA Hall.

Spiriferoid, transverse with nearly equally convex valves. Hinge line straight with abruptly rounded cardinal extremities. Surface plicate. Pedicle valve with median sinus; beak truncated by a circular foramen; delthyrium covered by two short plates resting upon the umbo of the opposite valve. Teeth prominent. Brachial valve with a median fold and with small and deep dental sockets. Cardinal process very prominent and elevated, divided into four parts by a deep longitudinal and a less prominent transverse groove. Distinguished externally from *Rhynchonella* and *Spirifer* by its punctate structure. Siluric–Devonic.

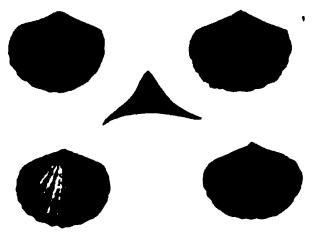


FIG. 443. *Trematospira camura* (Pal. N. Y., II.).

393. **T. camura** Hall. (Fig. 443.) Siluric.

Small, transversely elliptical to subrhomboidal. Valves almost equally convex. Sinus of pedicle valve marked by one or two small plications which die out toward the beak. Fold of brachial valve with two small plications which likewise become obsolete toward the beak. Surface marked by four to six plications on each side the median line and by concentric growth lines.

Niagaran of New York.

394. **T. multistriata** Hall. Devonic.

Brachial valve the more convex. Surface granulose or punctate, marked by many fine radial striæ and by concentric growth lamellæ.

Helderbergian of New York.

CXIII. PARAZYGA Hall and Clarke.

Differs from *Trematospira* externally only in the usually smaller and simple plications and in the surface covering of very fine and short spines; these are usually broken off, leaving only their bases. Internally it has a weak deltidial tube similar to that in *Hustedia*. Cardinal process low, bilobed; dental sockets broad. Devonic.

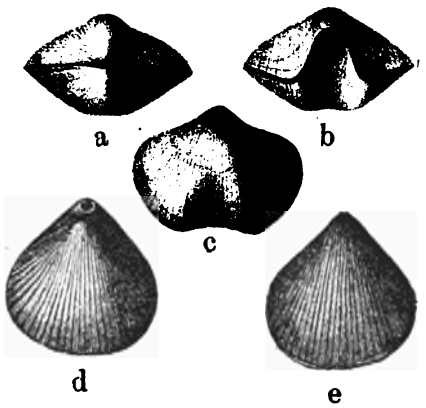


FIG. 444. *a–c*, *Parazyga hirsuta* (Pal. N. Y., II); *d–e*, *Eumetria marcyi* (Ind. Geol. Surv.).

395. **P. hirsuta** Hall. (Fig. 444, *a–c*.) Devonic.

Depressed orbicular. Pedicle valve curving regularly to the apex where it is terminated by a circular foramen. Surface marked with 30 to 40 low striæ which are most conspicuous towards the margin; these are crossed by fine concentric growth lines and more distant lamellæ. Shell punctate.

Onondaga and Hamilton of New York, Kentucky, Indiana, Ontario.

CXIV. EUMETRIA Hall.

Differs from *Rhynchospira* (No. CIX) merely in the greater complication of the parts of the hinge plate and in the variation in the form of the loop. Punctate. Mississippic to Carbonic.

396. **E. marcyi** (Shumard). (Fig. 444, *d–e*.) Mississippic.

Longitudinally ovate, almost equally biconvex. Beak of pedicle valve elevated and incurved and with a circular foramen. Surface marked by about 50 rounded, punctate striæ.

St. Louis and Kaskaskia of Tennessee, Missouri, Arkansas, Indiana, Iowa, Illinois.

CXV. WHITFIELDELLA Hall and Clarke.

Small, ovate or elongate, subequally biconvex. Beak of pedicle valve not high. Cardinal slopes of both valves broad and not distinctly defined. Anterior margin subtruncate. Median septum present in brachial valve. Surface smooth. Siluric–Devonic.

397. **W. cylindrica** Hall. (Fig. 445.) Siluric.

Elongate-cylindrical. Width and thickness nearly equal. Beak of pedicle valve strongly overarching. Faint mesial depression present in pedicle valve. Surface marked with fine radiating striæ near the front.

Clinton–Niagaran of New York, Ohio, Ontario, Anticosti.

Fig. 445. *Whitfieldella cylindrica* (Pal. N. Y. IV.).

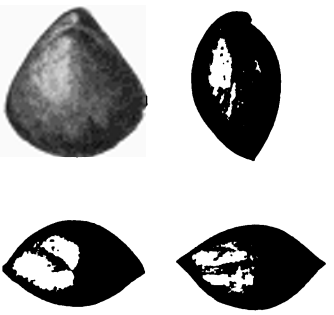


FIG. 446. *Whitfieldella intermedia* (Pal. N. Y., II.).

398. **W. intermedia** Hall. (Fig. 446.) Siluric.

Obovate, rapidly expanding toward the front which is abruptly rounded. Length and width nearly equal. Faint lines of growth on surface.

Clinton and Niagaran of New York, Pennsylvania, Ontario.

FIG. 447. *Whitfieldella nitida* (Pal. N. Y., II.).

FIG. 448. *Whitfieldella nitida* var. *oblata* (Pal. N. Y., II.).

399. **W. nitida** Hall. (Figs. 447–448.) Siluric.

Varies from broadly to narrowly ovate. Valves strongly and equally convex. Beak of pedicle valve pointed and incurved. Surface smooth except for concentric growth lines which are at times strongly marked. Often a slight sinus occurs near the front in both valves, producing a slight frontal emargination.

Niagaran of New York, Kentucky, Indiana, Ontario, Anticosti.

400. **W. ? nucleolata** (Hall). (Fig. 449.) Siluric.

Beak of pedicle valve pointed and incurved. Front of shell indented. Surface with concentric growth lines. This species is less elongate than *W. nitida* and the frontal indentation is more conspicuous.

Cobleskill of New York, Wisconsin.

401. **W. sulcata** (Vanuxem). (Fig. 450.) Siluric.

Distinguished by its elongate form, strongly ventricose character and well marked mesial sinus in the pedicle valve.

Cobleskill and Mantius of New York.

FIG. 449. *Whitfieldella nucleolata* (Pal. N. Y., II.).

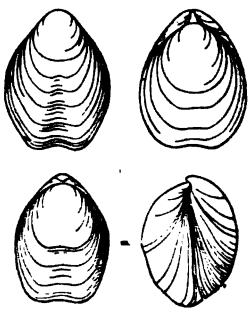


FIG. 450. *Whitfieldella sulcata*. (After Graham.)

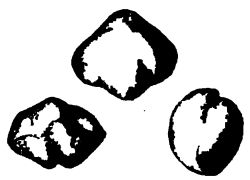


FIG. 451. *Hyattella congesta* (Pal.N. Y., II.).

CXVI. HYATELLA Hall and Clarke.

Small, nearly five-sided. Valves subequally convex. Differs from *Whitfieldella* in the form and in the absence of a median septum in the brachial valve. Siluric.

FIG. 452. *Hyattella congesta* (Pal. N. Y., II.).

402. **H. congesta** (Conrad). (Figs. 451–452.) Siluric.

Gibbous. Pedicle valve strongly convex with a deep median furrow which deepens and widens toward the front. Strong fold on brachial valve with a more or less prominent lateral fold on each side.

Clinton of New York, Pennsylvania, Ohio, Kentucky, Ontario.

CXVII. NUCLEOSPIRA Hall.

Small, subcircular, gibbous. Hinge line short. Valves nearly equal. Beak of pedicle valve slightly extended beyond that of opposite valve. Brachial valve with a large, hook-like cardinal process curved sharply posteriorly. Crura long and straight. A

FIG. 453. *Nucleospira pisiformis.* (After Hall.)

conspicuous median septum extends from beak to front in each valve. Surface in perfect specimens covered with numerous slender spines; these are usually worn off.

Siluric–Lower Carbonic.

403. **N. pisiformis** Hall. (Fig. 453.) Siluric.

Small. Each valve bears a slight depression down the center. Surface marked with fine concentric striæ.

Niagaran of New York, Kentucky, Indiana, Missouri.

404. **N. concinna** Hall. (Fig. 454.) Devonic.

Depressed spheroidal. Surface smooth, very finely papillose or when perfect covered with very fine spines.

Onondaga–Hamilton of New York, Pennsylvania, Virginia, Ohio, Kentucky, Indiana, Nevada, Ontario.

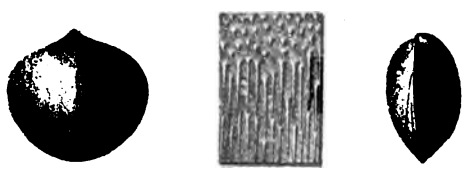


FIG. 454. *Nucleospira concinna* (Pal. N. Y., IV.).

CXVIII. ANOPLOTHECA Sandberger (emend. Hall and Clarke).

Pedicle valve convex, with incurved umbo. Brachial valve concave or flat more rarely convex with a high median septum. No cardinal area. Plications few, crossed by fine concentric growth lines, making the surface rough. Siluric–Devonic.

A. Shell large, over ½ inch wide.....408. *A. flabellites.*
B. Shell small, much less than ½ inch wide..... *.
* Brachial valve concave.....407. *A. concava.*
* Brachial valve flat or convex..... 1.
1. Hinge line straight.....405. *A. hemispherica.*
1. Hinge line curved.....406. *A. plicatula.*

405. **A. (Cœlospira) hemispherica** (Sowerby). (Fig. 455.) Siluric.

Hemispheric. Brachial valve flat. Hinge line nearly straight. Surface marked by 8 to 12 or more rounded simple plications which are crossed by strong concentric growth lines.

Clinton of New York, Kentucky, Tennessee, Georgia, Alabama, Nova Scotia, Anticosti.

406. **A. plicatula** (Hall). (Fig. 456.) Siluric.

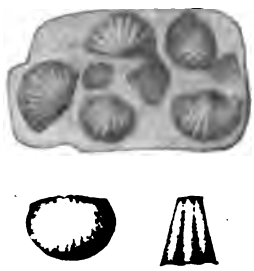


FIG. 455. *Anoplotheca hemispherica* with striæ enlarged (Pal. N. Y., II.).

FIG. 456. *Anoplotheca plicatula* (Pal. N. Y., II.).

Small, ovate. Valves subequal. Pedicle valve slightly carinate at umbo, with a slight median sinus anteriorly. Brachial valve almost flat toward the beak and elevated into a median fold anteriorly. Surface with two plications in sinus and three on fold with six to eight on each side. Concentric striæ not conspicuous.

Clinton of New York and Niagara of Wisconsin.

407. **A. concava** (Hall). Devonic.

Pedicle valve convex. Brachial valve flattened near lateral margins and at times depressed in the middle due to the rapidly widening sinus. Surface marked by rounded striæ, the one on the

FIG. 457. *Anoplotheca* (*Leptocœlia*) *flabellites* (Pal. N. Y., IV.).

mesial fold is generally smaller than the others giving the fold a slightly grooved appearance along its center quite to the beak.

Helderbergian of New York, and of Kennedy channel in Arctic region.

408. **A. (Leptocœlia) flabellites** (Conrad). (Fig. 457.) Devonic.
Pedicle valve convex, most prominently along the middle. Brachial valve flat. Sinus of brachial valve and fold of pedicle

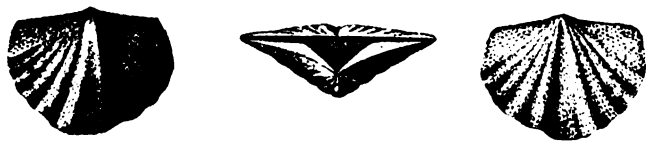


FIG. 458. *Vitulina pustulosa* (Pal. N. Y., IV.).

valve quite indistinct. Shell much larger and striæ less numerous than in *A. concava*.

Oriskany and Onondaga of New York, Maryland, Illinois, Ontario, Quebec.

CXIX. VITULINA Hall.

Small. Pedicle valve usually convex and brachial flat. Hinge line forming the greatest diameter of shell. Pedicle opening large and triangular. Cardinal process simple. Devonic.

409. **V. pustulosa** Hall. (Fig. 458.) Devonic.
On pedicle valve an elevated fold present with depression in its center; on brachial valve a sinus with a corresponding fold in the center. Surface marked with a few coarse rounded plications. Interrupted radiating lines give the shell a pustulose appearance.

Hamilton of New York, Pennsylvania.

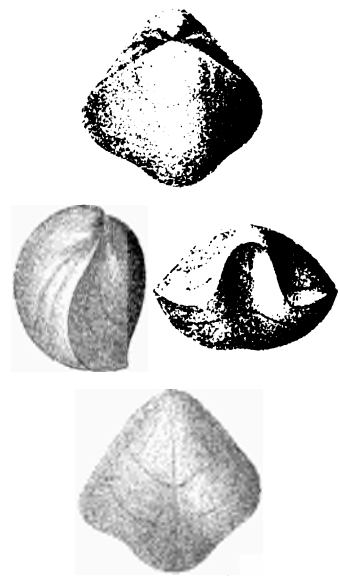


FIG. 459. *Meristina maria*. (After Nettelroth.)

CXX. MERISTINA Hall.

Like *Meristella* externally, differing merely in the character of the loop connecting the spirals. Siluric.

410. **M. maria** Hall. (Fig. 459.) Siluric.
Subquadrangular, gibbous, subequally biconvex. Beaks closely incurved. Pedicle valve with a broad sinus anteriorly and brachial valve with a corresponding fold. Surface marked merely with con-

centric growth lines. Length equalling or greater than the width.

Niagaran of Ohio, Tennessee, Kentucky, Indiana, Illinois, Wisconsin.

CXXI. ATHYRIS McCoy (emend. Hall and Clarke).

Subequally biconvex, varying in outline from subcircular to transversely elliptical. Beak of pedicle valve incurved, perforated by a round foramen which encroaches upon the umbo. Surface medially sinuate. Teeth prominent and recurved at the tips, supported by stout dental lamellæ. Brachial valve with broad and deep dental sockets and strong hinge plate; the large muscular areas well defined. Spirals laterally directed, with a large saddle shaped jugum, the anterior portion of which divides each branch uniting again with the primary lamella.

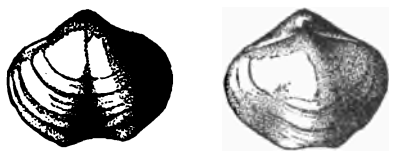


FIG. 460. *Athyris fultonensis* (Ind. Geol. Survey).

Siluric–Mississippic.

411. **A. fultonensis** (Swallow). (Fig. 460.) Devonic.

Differs from *A. angelica* in its subquadrate form and somewhat

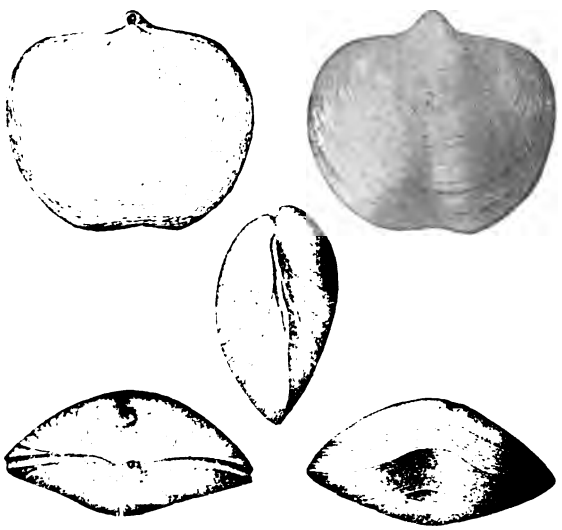


FIG. 461. *Athyris spiriferoides* (Pal. N. Y., IV.).

less prominent beak; from *A. spuriferoides* in its smaller size, the regularity of its lines of growth and the more prominent umbo.

Onondaga and Hamilton of Kentucky, Indiana, Michigan, Missouri, Iowa, Manitoba.

412. **A. spiriferoides** (Eaton). (Fig. 461.) Devonic.

Robust. Front indented by a deep sinus. Surface marked by coarse irregular concentric lamellæ.

Onondaga and Hamilton of New York, Pennsylvania, Maryland, Virginia, Ontario.

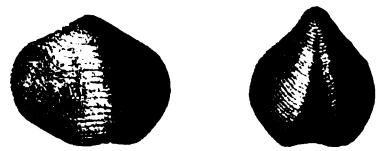


FIG. 462. *Athyris angelica* (Pal. N. Y., IV.).

413. **A. angelica** Hall. (Fig. 462.) Devonic.

Gibbous, deeply sinuate, with short hinge line and very prominent beak. Surface marked by regular, equidistant lamellæ.

Chemung of New York, Pennsylvania, Nevada.

414. **A. lamellosa** (L'Eveillé). (Fig. 463.) Lower Carbonic.

Length about two thirds of width. Hinge line long, nearly straight and rounded at extremities. Anterior margin usually produced and subangular in the middle at the termination of the mesial fold and sinus. Brachial valve slightly the more convex and

FIG. 463. *Athyris lamellosa* (Pal. Ohio).

rising into a low, rounded mesial fold. Pedicle valve with shallow mesial sinus. Surface of both valves with 8 or 10 strongly projecting lamellæ. Differs from other species in its transversely elliptical form.

Waverly–Keokuk of Ohio, Kentucky, Indiana, New Mexico.

CXXII. CLIOTHYRIS King.

Differs from *Athyris* in the surface ornamentation which here consists of concentric rows of flat spinules and also in the spirals and loop. Mississippic–Permic.

415. **C. roissyi** (L'Eveillé). Mississippic.

Differs from *C. hirsuta* in the unequal convexity of the valves, the brachial valve being regularly convex while the pedicle valve is convex above (near beak), but below is depressed and often flattened. It differs also in the scarcely incurved beak of the pedicle valve and in the character of the surface.

Keokuk–Kaskaskia of Mississippi Valley and western United States.

416. **C. hirsuta** Hall. (Fig. 464.) Mississippic.

Nearly equally biconvex. Beak of pedicle valve prominent and incurving over that of brachial valve. Surface marked by concentric imbricating lamellæ on which rise rows of minute spines.

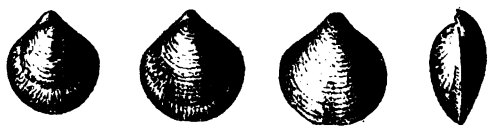


FIG. 464. *Cliothyris hirsuta* (Ind. Geol. Survey).

Sinus and fold absent, being represented merely by a slight depression in the front of the pedicle valve.

St. Louis and Kaskaskia of Kentucky, Indiana, Illinois, Montana.

CXXIII. SEMINULA McCoy (emend. Hall and Clarke).

Small. Differs from *Athyris* in the presence of a median sinus on the pedicle valve and a fold on the brachial with often an obscure fold on each side on both valves. Surface of valves smooth, never lamellose. Mississippic-Carbonic.

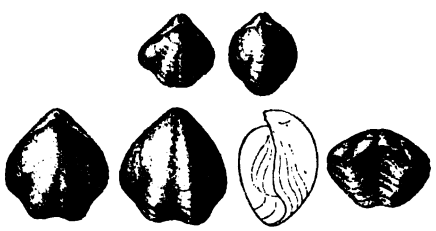


FIG. 465. *Seminula trinucleus* (Ind. Geol. Survey).

417. **S. subquadrata** Hall. Mississippic.

Subquadrate with length and breadth nearly equal. Brachial valve slightly the more convex and bearing a broad, mesial fold. Sinus of pedicle valve broad and deep and produced anteriorly. Surface marked concentrically with fine growth lines and toward the margin by strong lamellæ.

Kaskaskia of Ohio, Kentucky, Illinois, Utah.

418. **S. trinucleus** Hall. (Fig. 465.) Mississippic.

Differs from the preceding in having a depression on the center of the fold, and in the pronounced margins of the sinus, sometimes forming distinct ribs near the front.

St. Louis of Indiana, Illinois, Missouri and Kentucky.

419. **S. argentea** (Shepard) (*S. subtilita* Hall). (Fig. 466.) Carbonic.

Subovate, usually longer than wide, moderately gibbous. Pedicle valve slightly more convex than the brachial with prominent beak; mesial sinus becoming obsolete about the middle of the

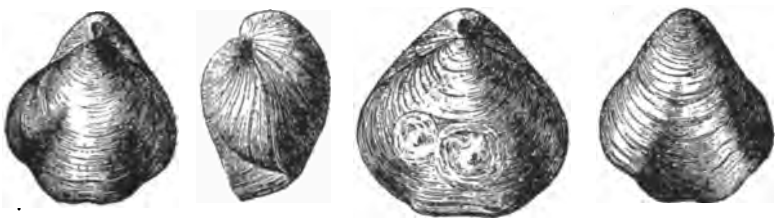


FIG. 466. *Seminula argentea*, one specimen with *Crania modesta* (No. 61) attached (Ind. Geol. Survey).

shell; a more or less distinctly impressed line usually extends along the bottom of this sinus from beak to front. Brachial valve with ill defined mesial fold. Surface marked with concentric striæ and faint traces of radiating lines. Average length about 1 inch.

Throughout the Upper Carbonic of North America.

420. **S. dawsoni** Hall and Clarke. (Fig. 467.) Carbonic.

Smaller and more triangular than preceding, with fold and sinus scarcely defined. Greatest width in anterior third of shell.

Windsor limestone of Nova Scotia — extremely abundant.

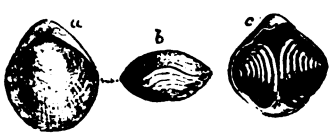


FIG. 467. *Seminula dawsoni.* (After Dawson.)

CXXIV. MERISTELLA Hall.

Oval to suborbicular. Valves unequally convex, with or without a faint median sinus or fold. Umbo of pedicle valve greatly incurved at maturity so as to conceal the open delthyrium. No cardinal area or spondylium present. Surface smooth or with fine concentric lines and very fine radiating

striæ. Brachial valve with a strong cardinal process from whose base extends a thin longitudinal septum half way down the valve. Muscular area broadly ovate. Devonic.

A. Width exceeding length ..... *.
  * Median sinus in both valves ..... 421. *M. bella.*
  * Median sinus in pedicle valve only ..... 424. *M. arcuata.*
B. Length exceeding width ..... **.
  ** Anterior margin truncate ..... 1.
    1. Small. Beak of pedicle valve extended ..... 426. *M. barrisi.*
    1. Large. Beak of pedicle valve closely incurved ..... 422. *M. lævis.*
  ** Anterior margin more or less prolonged into a linguiform extension. ..... 2.
    2. Greatest width of shell anterior to middle. Sinus in pedicle valve. 423. *M. princeps.*
    2. Greatest width of shell near middle. No sinus in pedicle valve. 425. *M. nasuta.*

421. **M. bella** (Hall). Devonic.

Valves of nearly equal convexity and both marked by a narrow mesial sinus which in meeting give the front an emarginate character.

Helderbergian of New York, Ohio, New Brunswick.

422. **M. lævis** (Vanuxem). (Fig. 468.) Devonic.

Ovate, gibbous. Somewhat resembles *M. bella* but differs in its

FIG. 468. *Meristella lævis* (Pal. N. Y., III.).

greater length proportionally and in the absence of a sinus on the brachial valve.

Helderbergian of Maine, New York, Pennsylvania, Ohio, Missouri, New Brunswick.

FIG. 469. *Meristella princeps* (Pal. N. Y., III.)

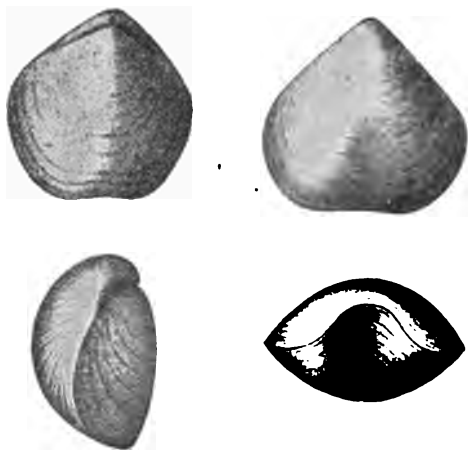


FIG. 470. *Meristella arcuata* (Pal. N. Y., III.).

423. **M. princeps** Hall. (Fig. 469.) Devonic.

Large, ovate, ventricose. Pedicle valve depressed anteriorly into a broad mesial sinus, terminating in old specimens in a linguiform extension. Brachial valve greatly elevated in the middle,

producing a strong mesial elevation anteriorly. Distinguished from *M. nasuta* in its greater width being anterior to the middle and in the presence of a sinus in the pedicle valve.

Helderbergian of New York, New Brunswick.

FIG. 471. *Meristella arcuata*, internal mold (Pal. N. Y., III.).

424. **M. arcuata** Hall. (Figs. 470, 471.) Devonic.

Broadly ovate to transversely oval. Pedicle valve bearing anteriorly a shallow depression. Brachial valve gibbous along the middle. Surface smooth except for a few faint radiating and concentric lines.

Helderbergian of New York and New Brunswick.

425. **M. nasuta** (Conrad). (Figs. 472 and 473.) Devonic.

Subrhomboidal with greatest width near the middle. Pedicle valve gibbous with prominent beak. Anterior margin marked by

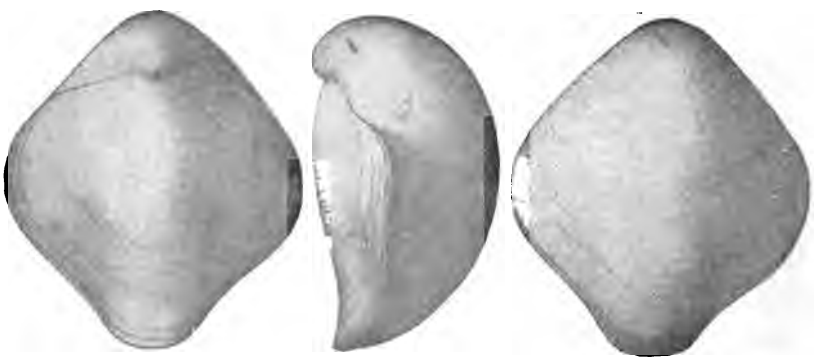


FIG. 472. *Meristella nasuta*, Schoharie form (Pal. N. Y., IV.).

a nasute extension. Brachial valve moderately convex and abruptly elevated toward the front into a short, rounded fold. Beak moderately incurved.

FIG. 473. *Meristella nasuta*, Onondaga form (Pal. N. Y., IV.).

Schoharie and Onondaga of New York, Ohio, Kentucky, Indiana, Nevada, Ontario.

426. **M. barrisi** Hall. (Fig. 474.) Devonic.

Ovoid, more or less elongate, sinuate anteriorly. Pedicle valve depressed toward the front with beak arching and not closely incurved. Brachial valve abruptly elevated near the anterior margin. Surface smooth or concentrically striated.

Marcellus and Hamilton of New York. Also in Russian Urals.

FIG. 474. *Meristella barrisi* (Pal. N. Y., IV.).

CXXV. PENTAGONIA Cozzens.

Pedicle valve with a very broad median sinus outside of which the lateral slopes are very abrupt. Muscular impressions like *Meristella*. Hinge plate rises vertically from the bottom of the pedicle valve; its anterior face bears a low, median plication on each side of which posteriorly rise the two short crura. The posterior face of the hinge plate bears a deep concavity. Devonic.

427. **P. unisulcata** (Conrad). (Fig. 475.) Devonic.

Subtrigonal, wider in front. Median sinus of pedicle valve occupying nearly the whole width of the valve and bounded on each side by an angular fold; umbo prominent and incurved over that

of brachial valve. Brachial valve gibbous in middle, the prominent mesial fold marked by a sinus extending to the beak. Surface bearing a few concentric growth lines and rarely concentric folds.

Oriskany–Hamilton of New York, Ohio, Kentucky and Ontario.

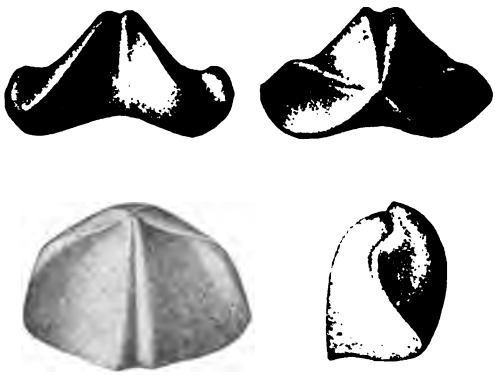


FIG. 475. *Pentagonia unisulcata* (Pal. N. Y., IV.)

PRINCIPLE AND OPERATION OF THE FÉRY RADIATION PYROMETER.

By C. H. WILSON and FREDERICK MAEULEN.

Copyright, 1907.

The radiation pyrometer of Professor Charles Féry is a practical works or laboratory instrument for measuring all temperatures over 500° C. (932° F.) by merely sighting a telescope at the hot

Fig. 1.

body or into a furnace and reading the result direct from a needle over the graduated scale of a millivoltmeter. It operates instantly, is accurate to within one per cent., has no batteries and requires no photometric comparison with the light from a standard lamp as do optical pyrometers, for it is operated by the heat radiations — the light from the hot body having nothing whatever to do with the principle on which this instrument operates. The telescope is focused whenever given a new piece of work to do and after focus-

ing (which operation is shown in Fig. 1, and takes but a few seconds) one pays no further attention to any part of the pyrometer but the indicating needle. The instrument, not the operator, does all the work of taking the temperature.

Anyone who has used an optical pyrometer to obtain the advantage of keeping all parts of the pyrometer out of the fire has, to obtain that, been subjected to great annoyance or defeat by the instability of the batteries and the varying condition of the lamp filament, by the continued restandardization of the instrument, which must be done every few hours when in use, and by the fact that each time a reading is taken the operator must make a color comparison, losing time and knowing that two operators will not read alike. None of those objections and annoyances is encountered in the radiation pyrometer, nor has it acquired other difficulties in their stead.

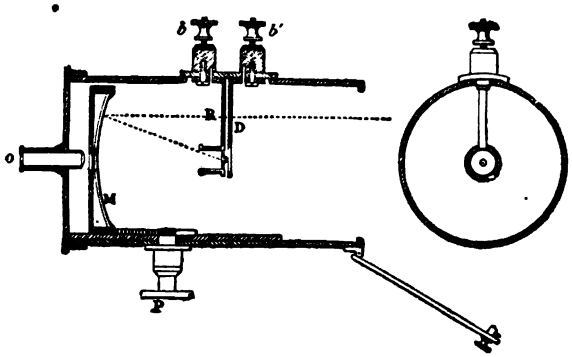
To understand the operation of the instrument it is necessary only to keep in mind the following: Heated bodies radiate heat to colder ones, and heat radiation is distinctly perceptible at lower temperatures than is light radiation. Heat rays may be reflected and brought to a focus just as can those of light and where, by means of a concave mirror, one obtains an optical image of a radiant body there will be found also what we might call the hot image. With a concave mirror one can burn a hole in wood or paper by focusing the sun's rays with it quite as readily as the same result can be obtained with a lens. In fact it is only because a lens was found to absorb too large a percentage of the radiations at the lower temperatures that recourse has been had to the concave mirror in constructing this pyrometer.

As the mirror is moved farther and farther from the hot body it receives less heat. From this it might seem that the image of the hot body would become less hot as the mirror is moved away, even considering that the body observed retains an even temperature. This is true if we consider the whole image. But as the mirror is moved away the image also becomes smaller in area, and it gets smaller in just the same proportion as that by which the total heat in the image is reduced, with the result that the smaller amount of heat in the image, being spread over a smaller area of image, gives the same quantity of heat per unit of area. Therefore if a piece of metal is placed at and in the image, and the mirror never moved so far from the hot body as to make the image too

small to wholly cover the metal, it is evident and true that the metal will receive an even and constant amount of heat though the mirror be moved in turn towards and away from the radiantly hot body.

It is also to be kept in mind that if two wires of dissimilar metals are brought together at one point (to be referred to as the thermo-junction), and their other ends connected by some electrical conductor, there will be a small electric current generated if the thermo-junction is heated to a higher temperature than the free

SECTION THROUGH TELESCOPE.



M — mirror
R —ray of heat
b and b′ — binding post
P—focusing screw

FIG. 2.

ends. In counterdistinction to the hot junction the cooler free ends are called the cold junctions. The voltage of the current increases with the difference in temperature between the hot and the cold junctions, but remains constant as long as the difference in temperature between the two junctions does. By interposing a millivoltmeter in the circuit between the two free ends of the "thermo-couple" (the dissimilar wires) there is furnished an accurate and sufficient means to read the voltage of the generated current. Each current value indicated in millivolts stands for so many degrees of temperature, and by standardizing the thermo-couple a table or chart of equivalents may be obtained.

Now in the Féry Radiation Pyrometer the thermo-couple wires are in a telescope and are made into a junction in such a position that the image of the hot body or of the radiations coming through

an aperture from a hot furnace can be focused upon that junction by a concave mirror also in the telescope. The cold ends of the wires are not far from the hot junction but are outside of where the hot image can be thrown. The "hot" and "cold" junctions are, however, so near that so far as being affected by the atmospheric temperature is concerned they would be of one temperature, and the whole difference of temperature between them is due to the heat focused upon the hot junction.

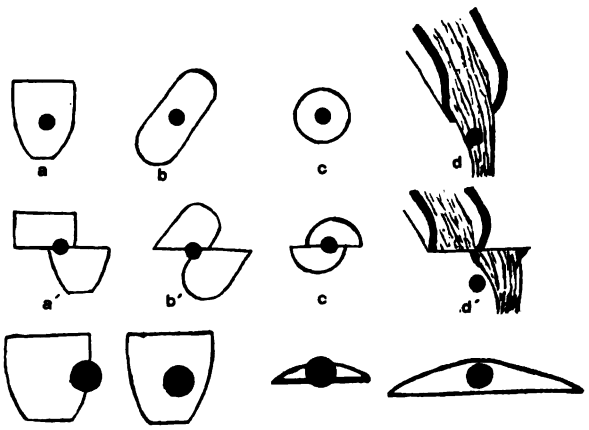
We have seen that a particle of metal, which the thermo-junction (hot junction) actually is, will receive the same amount of heat no matter whether the telescope containing it and the concave mirror be moved towards or away from the source of radiant heat, provided only that the hot image is large enough to more than cover the thermo-junction.

As the radiant body gets hotter the thermo-junction also is increased in temperature over that of the unaffected cold junctions and following out the effects it will be seen that the electric current increases in voltage and the needle of the millivoltmeter moves across its dial to a higher indication. The needle remains stationary, advances or retreats according as the radiant body remains constant in temperature, gets hotter or cools. In other words the needle swings with the temperature of the hot body under observation and it is only necessary to note its position over the scale which is calibrated so as to give the equivalent in temperature for each position of the needle.

The thermo-couple is rigidly fixed in the telescope but the position of the concave mirror, which is regulated by a thumb screw at the side of the telescope, must be altered each time the distance of the telescope from the observed hot body is changed. This is done to retain the focus of the rays upon the thermo-junction.

In putting the pyrometer into operation one looks through the telescope to know the proper position for the mirror, or, practically, so that one may know how much to turn the thumb screw which moves the mirror. The telescope is provided with an optical system such that when looking through the telescope the field of view seems to split into two halves, upper and lower. If the instrument is in focus the two halves will match or conform. By turning the thumb screw and destroying the focus one half is seen to move to the right and the other to the left and conformity is destroyed. The figures *a*, *b*, *c* and *d* illustrate the appearance

when there is focus and a', b', c' and d' the same objects when there is not focus. This definite method permits an accurate focus to be obtained in two seconds and the same for all eyes. The maker sees to it that the proper focus for heat exists when the optical focus is obtained and the one thumb screw controls both.



A black spot in the center of the field of view represents the thermo-junction and one must see that the radiant body as it appears through the telescope is larger than and wholly surrounds the black spot; if it does not the telescope must be moved closer to the source of heat. In practice it will be found that the telescope may be a yard away for every inch in diameter of the body or aperture if the same is round. With irregular bodies one can best adjust matters by looking through the telescope. In front of the eyepiece is pivoted a small red glass, which may be swung into place, so that when focusing the mirror, when very high temperatures are being measured, the eye is relieved from dazzling brightness.

The telescope both turns and dips by direct pressure from the hand and is easily sighted upon the body to be observed. It can also be clamped at a high or low position in the tripod socket. When sighted properly the hot body will be seen through the telescope to extend out beyond the black spot in all directions.

In Fig. 1 there may be noticed a diaphragm suspended from the front of the telescope. This same diaphragm in larger and front view is shown in Fig 3. When hanging down as in Fig. 1 it

obstructs none of the rays; when it is swung into place it absolutely closes the front of the telescope if the sliding shutter in the diaphragm is closed. The instrument should be so kept when not in use. By opening the diaphragm as far as possible it will be noticed that a little stop limits the extent of opening the shutter and when the shutter is used open it must be used as far open as it will go. In that position the diaphragm serves to obstruct or cut off a large per cent. of the radiations that otherwise would reach the mirror and it is intended for use in measuring temperatures over 1100° or 1200° C. (2012° or 2192° F.).

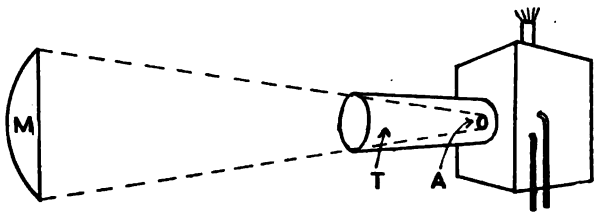
FIG. 3.

The millivoltmeter has three rows of graduations. The one in red is millivolts which are used only when checking up the accuracy of the instrument electrically. The two black rows of figures are degrees Centigrade, one ranging from 500° C. to 1100° C. or thereabouts and the temperature is to be read from that scale when the diaphragm is down. The other is from the neighborhood of 1000° C. to 2000° C. and is for use with the diaphragm up and shutter wide open. By this means there is derived the benefit of a very open scale equal to twice the actual length of scale.

The leads connecting the binding posts of the millivoltmeter to those of the telescope (which in turn are connected to the thermocouple are 33 feet long and separated at the ends into light and dark wound wires which must be fastened to light and dark colored binding posts respectively.

Sighting Through Tubes.

It sometimes happens that it is desirable or necessary to sight through a tube and here the question arises as to the minimum diameter of the tube. One had best always answer that for himself by considering the conditions of use. The instrument is calibrated to read correctly when none of the heat rays which it would normally receive are obstructed and prevented from reaching the mirror. The diameter of the mirror is 2¾ inches. The diameter of the circle from which it is receiving radiations of course varies with the focus. But it is readily seen that no obstructing body must be interposed between the mirror and the area it is focused upon. That space is the frustrum of a cone of which the mirror is the base, as may be seen in the diagram.



M = Mirror in telescope. *A* = Area focused upon or aperture in furnace wall. *T* = Tube one is sighting through.

In the diagram we show the tube *T* of one satisfactory size, *i. e.*, its walls do not cut off any part of the radiations, that is, it does not penetrate into the cone. But if the tube were of the same length and of smaller diameter it would evidently shut off some of the radiations. Similarly if it were longer and not larger in diameter it would penetrate the cone, cut off some of the radiations and lower the reading on the galvanometer. A series of two or three tubes of increasing diameters has been used where it is necessary that the part of the tube near the hot body or leading into the furnace shall be small in diameter.

Tubes are most frequently used with this pyrometer when it is desired to take the temperature of the interior of a furnace without having to open or leave open any port or aperture. One then uses a blind tube, *i. e.*, a tube (generally of fire clay) closed at its inner end, so that there is no in or out draft. The telescope in this case is focused upon the bottom of the tube.

Recording Attachment.

A very excellent recording instrument for measuring light electrical currents has been designed for use as a recorder in connection with the radiation telescope. It is absolutely practical, the records being clear and definite. Unique in design, sensitive in operation, it is still both robust and simple in construction.

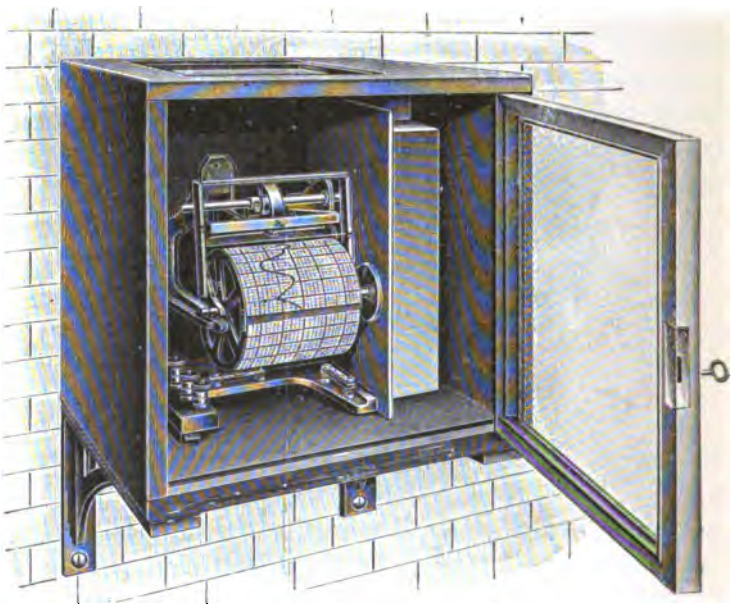


Fig. 4.

This recorder, Fig. 4, works on the principle of intermittent contact in the record making. It contains a galvanometer with a long stout knife-edge needle, over and across which there extends a boom supported at each end and raised and depressed by clockwork. Parallel to the boom but under the needle and between the latter and the traveling record paper is an inked thread which travels back and forth automatically, its reels being part of the clock system which drives the drum on which the record paper is mounted. The same clock system controls the boom, depressing it for a few seconds each half minute, so that it in turn depresses the needle, causing that point on the inked thread just under the needle to touch the paper and mark a point. It is the succession of these points (practically a line) that makes the record.

The speed of the drum may be adjusted quickly to either of two speeds: one revolution in twenty-four hours or in two hours and five minutes. By an original method of winding the needle deflections are such that the inked thread can be straight and is not curved in the arc corresponding to what is described by one point of the needle. This results in the rulings of the record paper being all straight lines at right angles.

This same recorder is perfectly adapted for use with thermocouples, in which case it should have a high internal resistance of manganin. In fact, one recorder can be made to serve with both the radiation telescope and with thermocouple, merely changing the connection by throwing a switch.

The instrument is also excellently adapted for use as a recording millivoltmeter or milliammeter when constructed with one or the other object in view. Double and quadruple recorders (not triple) are made so that in the one instrument may be made two or four separate and distinct records on double or quadruple width record sheets. This method places the several records in juxtaposition, with the time element the same in all the records. Not only is this a great convenience when several records are to be taken simultaneously, but by this consolidation of instruments into one there is obtained a considerable saving in expense. For each record there is a galvanometer in the recorder, but one boom and one drum and a single clock with the driving mechanism reduces the cost to much less than two or four single recorders, as the case may be.

INFLUENCE LINES FOR SUSPENDED CANTILEVERS.

By MYRON S. FALK, Ph.D.

The influence line method for determining the stresses in the usual type of cantilever structure may be found in Chapter IV. of "Influence Lines" by Burr & Falk. There is, however, a form of structure which although a true cantilever, possesses some of the lines of a suspension bridge, and the term of *suspended cantilever* might well be applied to it. Some general deductions as to the determination of its statical condition, and the application of the method of influence lines to determine the maximum stresses, will be found in the following article:

Statical Condition of the Structure.

In Fig. 1 is shown a coplanar frame work resting on the four points of support *A*, *B*, *C*, and *D*. Of these any one may be considered as fixed while all the others are supported on nests of rollers moving on horizontal beds. These conditions of support

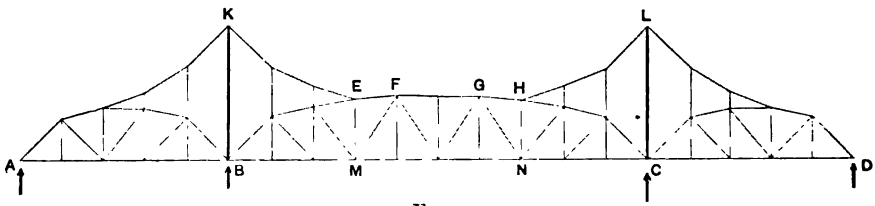


Fig. 1.

eliminate temperature stresses. The structure is then virtually a stiffened suspension bridge, the cable being *AKEFGHLD*, while the road bed lies along the lower chord *ABCD*.

If the structure be inverted and supported at the points *AKLD* of which only one is, as before, fixed, the framework becomes a continuous bridge of three spans; it is not subjected to temperature stresses. If the figure is, however, only supported at *K* and *L* as fixed points it becomes a two hinged arch subjected to temperature stresses.

In all these cases, therefore, Fig. 1 is a statically indeterminate framework; that is, the three equations of condition of coplanar

statics are insufficient for the determination of the stresses in the members. There are required in addition, other equations of condition, depending either on the elasticity of the material or the work performed in the structure by the displacement of its members.

The structure, as shown in the figure, may, however, be made statically determinate by the removal of the members EF and GH as shown in Fig. 1*a*, and by assuming the two panel points M and N to be frictionless pins. The structure is then a suspension

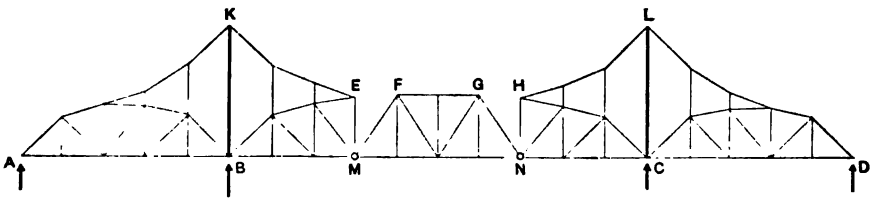
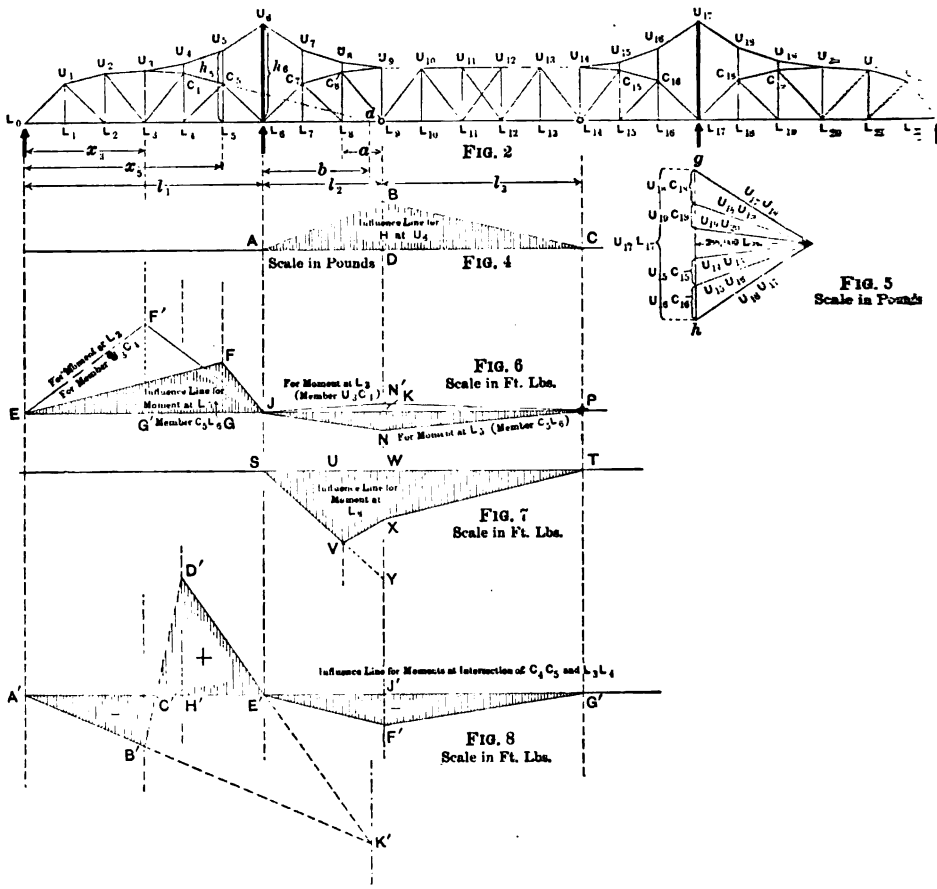


FIG. 1. *a*

cantilever in which the spans AB and CD are the anchor arms, the spans BM and NC the cantilever arms and MN is the suspended span. No difficulty will be experienced in determining for this class of structure the stresses due to dead load. The method of influence lines is, however, particularly applicable for determining the positions of the moving load causing the maximum stresses, as well as for determining the maximum stresses themselves.

Fig. 2 represents a suspension cantilever, the span $l_1 = L_0L_6$ being the anchor arm, the span $l_2 = L_6L_9$ being the cantilever arm and the span $l_3 = L_9L_{14}$ being the suspended span. The entire structure is taken to be symmetrical about the center of the panel $L_{11}L_{12}$. The distances measured between the lower panel points L and the upper panel points U are designated by h with a proper subscript; for instance, U_5L_5 is h_5 and U_6L_6 is h_6.

It will be assumed that the points L_0L_{23} are anchored and capable of carrying negative or downward reactions; the points L_6 and L_{17} are supported on nests of rollers moving on horizontal beds. For the static determination of the stresses and for the elimination of temperature stresses it also becomes necessary that one of the points of support of the suspended span be so carried that it may move horizontally over the end of the supporting cantilever arm; the point L_{14} of the suspended span may, for instance, be placed in a slotted hole.



FIXED LOAD STRESSES.

Fig. 3 shows a portion of the structure of Fig. 2 for which it is desired to obtain the stresses due to fixed load. For ease of illustration, the dead loads $W_1 W_2 W_3 \ldots W_9$ are all assumed to be supported at the lower panel points only. Their actual distribution between upper and lower chords would add, however, no difficulty to the work.

The reaction R_0 at L_0 may be obtained at once by taking the moments of all external forces about L_6 and placing them equal to zero. It is to be observed that the weight W_9 includes also one half the weight of the suspended span. The equation involving the reaction R_0 as the unknown quantity will then have the form

$$R_0 l_1 = \pm \Sigma W x$$

where x represents the distance of any panel weight from L_6 and is to be taken plus or minus as it is measured to the right or left of L_6.

The usual force polygon may then be constructed, taking at first the unknown forces L_0U_1 and L_0L_1 acting at panel point L_0 and balancing the reaction R_0. In order to simplify the terminology, the members will for the present also be designated by the numbers placed upon them. Having found, therefore, the stresses in the members 1 and 2, the stresses in the members 3 to 10 inclusive, taken in numerical order, may then be determined. At panel

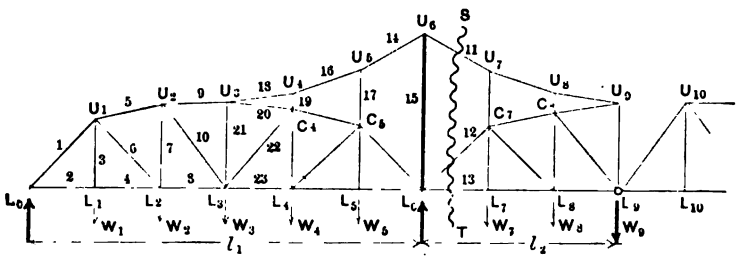


FIG. 3.

point U_3 there are, however, three unknown concurrent forces, and one of these must be known before the others can be found by means of the force polygon.

If a section ST be passed through the members 11, 12 and 13 the stress in the member 11 may be found by taking moments of all the external forces situated to the right of the section (namely, W_7, W_8 and W_9) about L_6 as the center of moments. The stress in member 11, multiplied by its lever arm about L_6 is then equal to the sum of the moments of these external forces. The stress in member 11 having thus been obtained, the stresses in members 14 and 15 may at once be determined, for they are the only two unknown forces acting at U_6. Panel point U_5 may then be treated in turn, and the stresses in the members 16 and 17 found. In precisely the same way there may then also be determined the stresses in the members 18 and 19.

One of the three unknown stresses at panel point U_3 has thus been found, and the determination of the stresses in members 20 and 21, or in any other members of the structure, presents no further difficulty.

Live Load Stresses.

In treating the live load stresses in the various spans of Fig. 2 it is first to be noted that the stresses in the suspended span l_3 are precisely the same as if that structure were a simple non-continuous span; that span requires, therefore, no further considerstion.

The anchor span l_1 is also a simple non-continuous span for any loads placed on that span only, the members U_3U_4, U_4U_5, U_4C_4, etc., not being considered as acting. Loads on the spans l_2 and l_3, however, cause stresses in the members of this span and these stresses must be investigated. Since they are caused by the stresses in the members U_3U_4, U_4U_5, and U_5U_6, and the suspender rods U_4C_4 and U_5C_5, these stresses must first be found. The horizontal components of all the upper chord members, such as U_4U_5, must necessarily be equal, since the only other members which are attached to them are vertical and carry no horizontal components. An influence line for the variation of this horizontal component as a load passes between the points L_6 and L_{17} will therefore be required.

Let there be placed a load P at L_9, the end of the cantilever arm l_2, and let a section be passed through the members U_6U_7, L_6C_7 and L_6L_7. The horizontal component of the stress in U_6U_7 may then be found by taking its moment and those of the external forces about L_6. The vertical component of U_6U_7, disappears in the moment equation since its lever arm about the center of moments is zero. If H represents the horizontal component, the following equation will result:

$$H \cdot h_6 = P \cdot l_2 \cdots \qquad (1)$$

or

$$H = \frac{P \cdot l_2}{h_6} \cdots \qquad (2)$$

Equation 2 shows that the value of H varies directly as the distance of the load P from L_6; this variation may therefore be indicated by a straight line for the span l_3. The influence line for H may therefore be drawn as follows (Fig. 4).

At the point D, situated on the base line AC directly below L_9 the ordinate BD is erected with a value $H = P \cdot l_2/h_6$, and the point B is then connected to A by a straight line.

Any load on the span l_3 is divided by the principle of the lever into two component parts, acting at L_9 and L_{14}; that part at L_{14}

causes no stress whatever in that portion of the structure to the left of L_9. That part of the load carried to L_9 varies directly as the distance of that load from L_9 and its effect on the influence line H may be represented by a straight line between L_9 and L_{14}, with a zero value at L_{14}. In Fig. 4 the influence line is therefore completed by connecting the point B to the point C. It is to be noted that this distribution of the load on the span l_2 causes every influence line between L_9 and L_{14} to be a straight line. Hereafter, therefore, if the value of the ordinate below L_9 is known, its end may at once be connected to a point on the base line directly below L_{14}.

It is seen that every load on the spans l_2 and l_3 increases the value of H; the maximum value of H is therefore found by covering the spans l_2 and l_3 completely; if the load be taken as a uniform load (which it is proper to do for long spans) the area of the triangle ABC multiplied by the intensity of the uniform load will furnish the maximum value of H.

Let the following data apply to this bridge:

$U_1L_1 = 30$ feet $= h_1$,
$U_2L_2 = 38$ feet $= h_2$,
$U_3L_3 = 40$ feet $= U_9L_9 = U_{10}L_{10} = U_{11}L_{11} = h_3 = h_9$, etc.,
$U_4L_4 = 45$ feet $= U_8L_8 = h_4 = h_8$,
$C_4L_4 = 38$ feet $= C_8L_8$,
$U_5L_5 = 55$ feet $= U_7L_7 = h_5 = h_7$,
$C_5L_5 = 30$ feet $= C_7L_7$,
$U_6L_6 = 75$ feet $= h_6$.

All panel lengths are taken equal at 30 feet each; the span l_1 is therefore 180 feet, the span l_2 90 feet and the span l_3 150 feet.

The value of H for a load of unity at L_9 is therefore, $\frac{90}{75} = 1.2$ and the ordinate BD is drawn with that height. The area of the triangle ABC is then $240 \times 1.2/2 = 144$ and if the intensity of the loading be taken at 2000 pounds per linear foot of truss, the maximum value of H becomes 288,000 pounds. The maximum stresses in the vertical suspender rods and upper chord members U_3U_4, U_4U_5 etc., will then be found by means of the simple force diagram shown in Fig. 5. For clearness of illustration the right-hand tower $U_{17}L_{17}$ instead of the left-hand tower is treated.

The horizontal force H is first laid down to proper scale and from one end of it are drawn lines parallel to $U_{17}U_{18}$ and $U_{18}U_{17}$ until these lines intersect the vertical gh erected at the left end of H. These lines, when measured to scale, furnish the maximum

stresses in those members. The stress in the tower column $U_{17}L_{17}$ is found in the same force triangle; its value is the distance gh or the vertical intercepted by the lines just drawn.

The maximum stresses in the suspender rods and upper chord members are found in the same figure by drawing lines respectively parallel to $U_{18}U_{19}$, $U_{19}U_{20}$, $U_{14}U_{15}$, etc. The stresses found for these members are clearly indicated in the figure. They are found from the simple principle of the force polygon as applied to the equilibrium of concurrent forces, for at any point, such as U_{16} there are to be determined only two unknown forces $U_{15}U_{16}$ and $U_{16}C_{16}$.

Influence Lines for the Chord Members of the Anchor Span, L_0L_6.

The influence line for the member C_5L_6 of the span l_1 will first be drawn. It has already been shown that, for loads on the span l_1, the members of the anchor span are to be treated as if that span were a simple non-continuous span. For that condition, then, the stress in the member C_5L_6 is found by passing a section through the members U_5U_6, C_5L_6 and L_5L_6. Since the member U_5U_6 is supposed not to be stressed, the center of moments may be taken at L_5.

Since the stress in C_5L_6 is equal to this moment at L_5 divided by a lever arm, its variation may be represented by the variation in the bending moment at L_5, and Fig. 6 represents the influence line for the moment at L_5. For the span l_1 this line is EFJ; the value of the ordinate FG is found by placing a unit load (1 pound) at L_5; the reaction at L_0 is then $R_0 = \frac{1}{6}$ and its moment about L_5 is $\frac{1}{6} \times 150 = 25$ foot pounds or FG.

When loads are placed on the pans l_2 and l_3 the member U_5U_6 is stressed; but in taking moments about L_5 for the stress in the member C_5L_6 it will only be necessary to consider the horizontal component of the stress in U_5U_6, for the moment of its vertical component disappears, its lever arm being zero.

Let there be placed a load P at L_9 and let it be required to find the moment at L_5 for that position of the load. The reaction at L_0 is upward and is equal to

$$R_0 = \frac{P \cdot l_2}{l_1}. \qquad (3)$$

If H represents the horizontal component of the stress in any upper chord member, the bending moment M_5 at L_5 is then given by the following equation:

$$M_5 = R_0 \cdot x_5 - H \cdot h_5. \tag{4}$$

Substituting the values of R_0 and H from Eqs. (3) and (2),

$$M_5 = P\left(\frac{l_2 \cdot x_5}{l_1} - \frac{l_2 \cdot h_5}{h_6}\right). \tag{5}$$

Substituting the numerical values of these quantities, and assuming P to be a unit load,

$$M_5 = \left(\frac{90 \times 150}{180} - \frac{90 \times 55}{75}\right) = 9 \text{ foot pounds.}$$

The ordinate KN, below L_9 is drawn downwards with this value, for it causes a tensile stress in C_5L_6.

It is to be noted that the value of M_5 as given by Eq. 5 varies directly as l_2, or the distance of the load from L_6. The influence line (Fig. 6) for the spans l_2 and l_3 may therefore be completed by drawing straight lines from N to J and P. The shaded areas show the portions of the structure to be covered by loading, to cause the maximum stresses of opposite kinds; it is to be remembered however, that these areas are moment areas, and are to be divided by the lever arm of C_5L_6 in order to furnish stresses.

The value of the maximum moment, causing compression in C_5L_6 is

$$\text{area } EFJ \times 2000 = \frac{180 \times 25 \times 2000}{2} = 4{,}800{,}000 \text{ foot pounds,}$$

while that causing tension, is

$$\text{area } JNP \times 2000 = \frac{9 \times 240 \times 2000}{2} = 2{,}160{,}000 \text{ foot pounds.}$$

The influence line for the member U_3C_4 is shown in the same figure as $EF'J$ for the span l_1 and as $JN'P$ for the spans l_2 and l_3. For the latter spans, the stress is compressive just as for the span l_1, as the evaluation of Eq. (5) shows. Moments are taken about the panel point L_3, and there is found, for a load of 1 pound at L_9:

$$M_3 = \frac{90 \times 90}{180} - \frac{90 \times 40}{75} = -3 \text{ foot pounds.}$$

The ordinate $G'F'$ is found by placing the unit load at L_3; the

reaction R_0 becomes ½, and the moment ½ × 90 = 45 foot pounds.

The influence line for a chord member, such as U_1U_2 is found in precisely the same manner by means of the same equations; in Eq. (5) however the term involving H disappears, and there is to be used

$$M_1 = P\frac{l_2 \cdot x_1}{l_1}. \qquad (5a)$$

Influence Lines for the Chord Members of the Cantilever Arm L_6L_9.

The influence line for the member C_7C_8 will be drawn; it is at once evident that loads on the span l_1 cause no stress in any of the members of the spans l_2 or l_3, and that span need not be considered.

The stress in C_7C_8 is found by passing a section through U_7U_8, C_7C_8, C_7L_8 and L_7L_8, and dividing the bending moment at L_8, by the lever arm of C_7C_8 about that point. The stress in U_7U_8 may be found, for any position of the load; its horizontal component need only be considered, for the moment of the vertical component disappears as its lever arm is zero.

If a load P be placed at L_8, the moment M_8 at L_8 is

$$M_8 = H \cdot h_8. \qquad (6)$$

But

$$H = \frac{P(l_2 - a)}{h_6}$$

therefore

$$M_8 = P \cdot \frac{(l_2 - a)h_8}{h_6}. \qquad (7)$$

For any position of the load between L_6 and L_8, Eq. (7) shows that M_8 varies directly as the first power of the variable distance $(l - a)$, this variation may therefore be represented by the straight line SV in Fig 7, the ordinate VU directly below L_8 having the value furnished by Eq. 7.

If a load be placed at L_9, the moment becomes

$$M_8 = H \cdot h_8 - P \cdot a. \qquad (8)$$

The value of the ordinate XW of the influence line erected at L_9 is therefore found by continuing the line SV to intersect the vertical dropped from L_9 and subtracting from it $P \cdot a$.

The influence line is then finally completed by connecting X and T by a straight line.

Substituting the numerical qualities in Eq. (7) and assuming P to be 1 pound there is found,

$$M_8 = \frac{(90 - 30)45}{75} = 36 \text{ foot pounds} = UV.$$

The value of XY is $I \cdot a = 30$ foot pounds.

The shaded area of Fig. 7 when multiplied by the intensity of the uniform load, furnishes the maximum bending moment at L_8. When divided by the lever arm there will be obtained the maximum stress, which is compressive.

INFLUENCE LINE FOR WEB MEMBERS OF THE ANCHOR SPAN L_0L_8.

The influence line for the member C_4L_4 will be drawn; its stress is found by passing a section through U_4U_5, C_4C_5, C_4L_4 and L_3L_4, and dividing the bending moment found at the intersection d of CC_{54} and L_3L_4, distant b from L_6, by the lever arm of C_4L_4. It will then only be necessary to draw the influence line for moment at that point; the stress in C_4L_4 may be found directly from that moment.

LOAD ON SPAN l_1.

The influence line for the load at any point of the span l_1, is found just as if that span were a simple truss; lines are drawn (Fig. 8) from any point K', found at any point directly below the center of moments, to points on the base line A' and E', directly below the ends of the simple span. The lines $A'B'$ and $D'E'$ are then portions of the influence line. In the panel L_3L_4, the influence line is also a straight line, and the line is finally completed by connecting B' and D' by a straight line.

If a load P be placed at L_4, the reaction at L_0 becomes in the present case $R_0 = \frac{1}{8}P$; and the moment of the external forces situated to the left of the section passed, is

$$M_d = \frac{P}{3}(l_1 + b) = P\left(\frac{180 + 82.5}{3}\right) = 87.5\,P.$$

If P be taken equal to 1 pound, the value of the ordinate $D'H'$ (Fig. 8) is therefore 87.5 foot pounds. This value determines the scale of this portion of the influence line.

LOAD ON SPANS l_2 AND l_3.

For a load placed on the spans l_2 or l_3, it will be necessary to obtain the stress in the member U_4U_5, for that stress appears as an unknown quantity in the equation of moments about the center of moments c.

It will be more convenient, however, to treat the horizontal and vertical components, H and V, of that stress.

Placing a load P at L_0, the moment M_d at d, then becomes:

$$M_d = R_0(l_1 + b) - Hh_4 - V(b + l_1 - x_4) \qquad (9)$$

but

$$R_0 = P\frac{l_2}{l_1}, \quad H = P \cdot \frac{l_2}{h_6}, \quad \text{and} \quad V = H \tan a$$

where a is the angle between the member U_4U_5 and a horizontal. Since $\tan a = \frac{(h_5 - h_4)}{p}$ where p = panel length,

$$V = P \cdot \frac{l_2}{h_6}\frac{(h_5 - h_4)}{p}.$$

Substituting these quantities in Eq. (9),

$$M_d = P\left[\frac{l_2}{l_1}(l_1 + b) - \frac{l_2}{h_6}h_4 - (b + l_1 - x_4)\frac{l_2}{h_6}\frac{(h_5 - h_4)}{p}\right]. \qquad (10)$$

Inspection of Eq. (10) shows that, for a load placed between L_6 and L_0, M_d varies directly as l_2 or the distance of the load from L_6; this variation may therefore be represented by a straight line $E'F'$ in Fig. 8, the ordinate $J'F'$ being given by Eq. (10). If P equals 1 pound, that equation becomes, for the example treated:

$M_d = \frac{90}{180}(180 + 82.5) - \frac{90}{75} \cdot 45 - (82.5 + 180 - 120)\frac{90}{75}(\frac{10}{80})$
$= 20\frac{1}{4}$ foot pounds.

The stress corresponding to this moment is compressive. The influence line is completed by connecting the points F' and G' by a straight line.

The final influence line (Fig. 8) shows that the greatest tension in C_4L_4 occurs when the distance $C'E'$ is covered by the uniform load; the greatest compression is found when spans l_2 and l_3, and the portion $A'C'$ of span l_1 are covered.

It is to be remembered that the shaded areas shown in Fig. 8 are moment areas, and must be divided by a lever arm to furnish stresses.

The influence line for any web member, such as U_2L_2, not lying below the cable members U_3U_4, etc., is also found by the use of Eq. (9), precisely as in the case of C_4L_4; but the terms in that equation which involve H and V disappear.

INFLUENCE LINE FOR WEB MEMBERS OF THE CANTILEVER ARM L_8L_9.

The influence line for the member C_8L_8 of the cantilever arm is shown in Fig. 10. The necessary parts of structure for determining that line are shown in Fig. 9. Loads placed on the anchor span l_1 cause no stresses in this member.

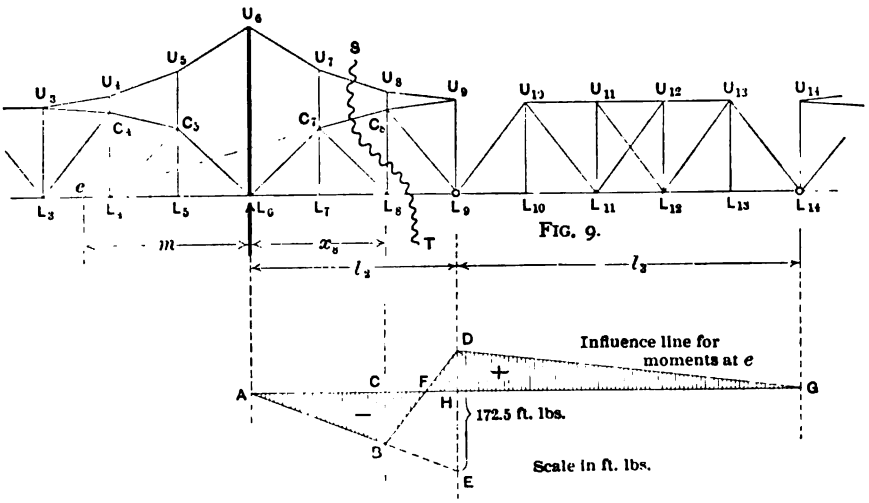


FIG. 9.

FIG. 10.

The stress in C_8L_8 is found by passing the section ST shown, and dividing the moment of the proper external forces taken about e as a center, by the lever arm of C_8L_8. As in previous cases, therefore, the moment influence line for the moment M_e of the external forces taken about e will be drawn, since the stress in C_8L_8 may be found directly from it. The horizontal and vertical components of stress in U_7U_8 are denoted by H and V respectively, while m and x_8 are the distances shown in the figure. If a load P, of one pound, be placed at L_8, the equation of moments about e, treating U_7U_8 as the external force, will be:

$$M_e = H \cdot h_8 + V(m + x_8). \qquad (11)$$

But

$$H = \frac{P(x_8)}{h_6} \quad \text{and} \quad V = H \tan \alpha,$$

if α represents the angle between U_7U_8 and the horizontal. Therefore,

$$M_e = \frac{P \cdot x_8 \cdot h_8}{h_6} + \frac{P \cdot x_8(m + x_8)}{h_6} \tan \alpha. \qquad (12)$$

Eq. (12) shows that M_e varies directly as x_8; since this term appears in the first degree, the equation may be represented by the straight line BA in Fig. 10, the ordinate BC having the value as furnished by Eq. (12). For the structure under consideration, Eq. (12) becomes

$$M_e = \frac{60 \times 45}{75} + \frac{60(82.5 + 60)\,1}{75\quad 3} = 74 \text{ foot pounds.}$$

The influence line passes through A, a point on the base line, for a load at that point causes no stress in C_8L_8.

If a load P of 1 pound be placed at L_9, the equation for M_e becomes

$$M_e = \frac{P \cdot l_2 \cdot h_8}{h_6} + \frac{P \cdot l_2 \cdot (m + x_8)}{h_6} - P(l_2 + m). \qquad (13)$$

Inspection of Eq. (13) shows that the first two terms of the right-hand member represent a continuation of the line expressed by Eq. (12). The third term shows that there must be subtracted from each ordinate of that line between L_8 and L_9, the value of P multiplied by its distance from e.

In Fig. 10 there must be subtracted from the ordinate EH the moment $P(90 + 82.5) = 172.5$ foot pounds.

The final influence line is therefore $ABDG$; the area FDG indicates a tensile stress, and the area ABF a compressive stress.

Suspension Cantilever with Two Points of Support at Intermediate Pier.

Fig. 11 shows the suspension cantilever, treated in the preceding articles, but in which the post U_6L_6 has been replaced by two columns, connected at top and bottom by horizontal members U_6U_6' and L_6L_6', but otherwise with no bracing between them. No shear can then be transferred past L_6' to the left or past L_6 to the right.

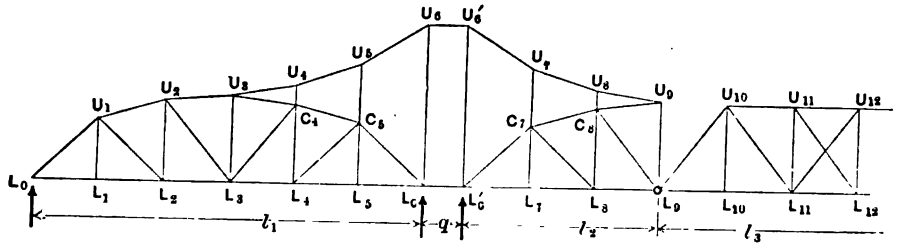


FIG. 11.

No change occurs, therefore, in any of the preceding constructions in determining R_0 or any of the stresses in the structure; it is necessary to observe that the open panel L_6L_6' is to be treated as a point, or entirely neglected. Changes occur, however, in determining the reactions R_6 and R_6' at L_6 and L_6' respectively; the stresses in the members U_6U_6' and L_6L_6' must also be found. These conditions are, however, precisely the same as those for the ordinary cantilever structure, supported on towers,* and they need not be considered in detail.

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* See Burr & Falk's "Influence Lines for Bridges," p. 158.

NOTES ON THREE-PHASE TRACTION.*

By GERARD B. WERNER.

The Electrification Problem in General.

The substitution of electricity for steam as motive power for train haulage is to-day contingent on financial and not technical considerations. There are at present three electric systems worthy of attention, and the engineering difficulties incurred in the development of each may be fairly said to have been overcome. The question, then, of the adoption of electric traction by steam railroads becomes a question of reduced operating costs or increased earning capacity.

The electric equipment required for trunk line service involves a very great investment. The writer has in mind a project for the electrification of an 80-mile, double-tracked section, with an annual traffic of about 1,500,000,000 ton miles, which called for the expenditure of approximately $2,500,000 (deducting the value of the steam locomotives replaced). The fixed charges on this capital must, of course, be charged to the operating expenses, and still a material saving must be effected in order that a respectful hearing may be accorded to the proposition by the railroad management.

The analysis of the costs of steam and electric locomotive operation formed the subject of a paper recently contributed by the writer to the technical press; † and he will therefore merely allude here, in passing, to the reduction in the several items which constitute the locomotive-mile cost. An understanding of such reductions will be facilitated, if it is borne in mind that for a given service, about one half the number of locomotives will be required with electricity as motive power. This consideration follows from the facts that (1) a large portion of the life of a steam locomotive is spent in the repair-shop; (2) and that a still larger portion is consumed in firing up and preparing for a run, and in withdrawing the fire and cleaning boiler tubes, after the daily run. So that the average daily mileage of an electric locomotive may be taken as double that of the steam locomotive in similar service.

* A paper read before the Electrical Engineering Society of Columbia University, February, 1907.

† *Engineering Magazine*, March, 1907.

Repairs may be reduced to 20 per cent. of the amount required with steam operation, on account of the absence of the fire, high pressure steam-pipes, frictional surfaces, and other parts subject to deteriorating influences.

Wages of engine and roundhouse men are only about 50 per cent. Even if the motorman and helper command the same salary as the engineer and fireman, the mileage each shift performs is about double.

Roundhouse-shop expenses including repairs and renewals on the roundhouse, shop and machinery, and other expenses, are also only one half, since the accommodations required are greatly reduced by the smaller number of locomotives to be handled, and the smaller time consumed by these departments.

Fuel and water-station operation, repairs and renewals are entirely eliminated.

Fuel is reduced to one half, as shown by the records of the Interborough system; although if we consider the cost of power delivered at the locomotive, inclusive of all operating and fixed charges on the power-station, transmission lines and sub-stations, this item is greater for electric operation. The fuel itself is used at about the rate of 6.86 lbs. per I. H. P. hour or .48 lb. per ton mile in the steam locomotive, and at the rate of 2.6 lbs. per kw.hr. or .16 lb. per ton mile at the power-house.

Oil, waste, grease and other supplies are likewise decreased one third — which fact is readily understood when we consider the smaller number of machine parts.

Depreciation is about 70 per cent. of that chargeable to steam locomotives. In this connection it must be remembered that although the average life of a steam locomotive is only about 13 years against about 20 years for its electric competitor, the value of the electric locomotive, upon which the amortization charge is based, is about 2½ times that of the steam locomotive.

The total saving in locomotive operation is shown to be from 16 per cent. to 22 per cent. with electricity, averaging about 18 per cent. With a fair traffic density, this would mean several hundred thousands of dollars, on lines with about three billion ton miles per annum.

Some roads, however, undertake electrification, "not to save money, but to make money"; that is, the increased earning capacity of the present tracks rather than reduction in operating expenses, becomes the compelling argument.

Raising the earning power of a road follows directly from the use of an electric locomotive which has a greater horse-power capacity per ton of weight. Thus an electric locomotive can be designed for about 2500 H. P. with a weight of 100 tons; while, for example, the compound Atlantic type No. 3000 of the N. Y. C. & H. R. R. R., with a total weight, including tender, of 161 tons, has a maximum continuous capacity of 1600 H. P. The steam locomotive of course is encumbered with the additional dead weight of the loaded tender, and through the exigencies of the boiler, is incapable of any sustained overload.

The greater horse-power capacity of the electric unit makes possible the handling of a higher traffic density per mile of track by three factors; the use of higher accelerations, greater running speeds and heavier trains.

For suburban service, where the runs are short and the stops frequent, the question of acceleration is of great importance. Although the electric and the steam locomotives may have approximately the same weight on drivers, and the starting tractive efforts consequently about equal, the initial acceleration can be maintained up to a very much higher speed in the case of the electric locomotive. This factor considerably affects the duration of the acceleration period, assuming the same train weights in both cases.

The greater horse-power capacity of the electric locomotive makes a higher tractive effort available at the running speeds; hence for the same train weight, a higher schedule speed is possible; and for the same running speed a train of heavier composition can be hauled. Both of these considerations eliminate the limitations imposed on the steam locomotive by the "ruling grade," since gradients may be taken at higher speeds or with heavier trains.

The removal of track congestion, due to the fact that higher speeds are possible with heavier trains, raises the revenue bearing train mileage and the net income, independent of the greater number of passengers who utilize the better facilities afforded by better schedules, more frequent service and the greater degree of safety and comfort.

Besides the reduction in operating costs, and increase in revenue capacity, electricity as motive power presents some incidental advantages of no mean importance. The smaller wear and tear on the track, structures and roadbed, due to the absence of the violent lat-

eral swaying and heavy hammer blows caused by the partially reciprocating balanced parts of the steam locomotive is very marked at high speeds. The elimination of smoke, cinders and the gases of combustion, reduces the maintenance of the rolling stock by rendering the necessity for car-body painting and cleaning less frequent, and is conducive to greater comfort of the traveling public and greater safety in tunnel operation. The greater facility of train movement which follows from the simplicity of control; the greater readiness for service and a greater factor of reliability all have considerable influence for the adoption of electric motive power for train haulage.

Structural Features of the Three-Phase Locomotive.

The current collectors consist of two long rollers mounted on the same wooden shaft, and rotating in ball bearings. The current is taken from them by carbon brushes. They give a broad contact surface of 24¾ inches for each phase, the distance between the two wires being about three feet. Four years of actual service on the roads of Germany, Switzerland and Italy have proven the claims made for this construction; viz.:

It combines the advantages of the trolley wheel in rolling friction with the broad contact of the Siemens bow.

It is perfectly safe and practically sparkless even at 200 amps. at 40 m. p. h., and 100 amps. at 60 m. p. h.

In the latest form of a steel tube contact cylinder, covered by a sheet of electrolytic copper, it is good for 12,000 locomotive miles. The maintenance and repairs are consequently small. The abrasion on the trolley wire is minimized, no sign of wear being visible except a polished surface about $\frac{1}{8}\frac{1}{2}$ inch broad on the under side.

The current collectors are actuated by compressed air, and the pressure against the working conductor is adjusted to the running speed.

As will be pointed out further on, the intermediate speeds on the controller are secured by the insertion of resistance in the rotor circuits. The Valtellina line uses water rheostats instead of the usual metallic grids. Compressed air moves the water to and from the contact plates, thereby producing a variable resistance. The pneumatic valves are actuated by relays from the main controller. The advantages of the water rheostat are lighter weight and less repairs. Burnouts are not possible, since the overload capacity is

large. Starting can also be effected more smoothly in the absence of the coarsely graduated steps of the metal resistances.

Another unique feature of the three-phase locomotive is the driving mechanism. For motors of several hundred horse power gears are not admissible, since they involve difficulties of design, occupy valuable space, and increase the energy consumption by about 3 per cent. Direct coupling is a satisfactory solution for motors of the series type, as in the New York Central locomotives where bipolar machines with tangential pole faces and a large air-gap are used. But with induction motors, where, on account of the distributed winding, no vertical movement is possible and the case is in one piece, the wheels would have to be pressed off the axle to make the motor accessible for repairs. The motors of the three-phase locomotives are mounted between the driving axles and drive the axles by crank-pins and coupling rods.

The advantages of this drive are (1) the facility of removing the motors for repairs; (2) the collector rings and brushes are outside the locomotive frame, and readily accessible for inspection; (3) the danger of the motors sharing the load disproportionately is obviated, since all the axles are driven at the same speed (which would not be the case if the axles were driven separately and there was a small difference due to wear in the diameters of the drivers); and (4) the energy loss in the mechanism is small.

The Induction Motor *per se*.

A number of objections are continually urged against the induction motor in regard to its possibilities for railway work. None of these objections appears valid on analysis.

In point of efficiency, the induction motor is far superior to the series motor either of the direct current or single phase type. The efficiency of the latter two may reach 88 per cent. and 84 per cent. respectively, while that of the induction motor for railway service is about 95 per cent. in single connection. At starting, in cascade connection the efficiency is about 88 per cent. The higher efficiency of the induction motor both in starting and running is probably conceded by all designers.

Similarly, the power factor in single connection and cascade is about 93 per cent. and 85 per cent. respectively for all loads above one quarter of the rating. These figures may be compared to those of the New Haven motors, which vary from 70 per cent. to 92 per cent. throughout the range of loads.

In point of weight, for the same conditions of speed and output, the three-phase motor weighs only about 80 per cent. of the direct current, while compared to the single phase, the difference is still more marked. This fact is due to the smaller losses in the induction motor, to the more economical distribution of copper and iron, and to the better facility for heat radiation. The cost, which may be taken proportional to the weight, is correspondingly lower.

With regard to starting torque, the induction motor can develop any tractive effort up to full adhesion weight, by starting with the rotor resistance. The induction motor moreover can utilize a constant input up to the maximum running speed, while the motors of the series type accelerate at a constantly diminishing rate with a correspondingly decreasing input as soon as the motor curve is reached. This fact enables the induction motor to attain a higher average acceleration, under similar conditions.

The overload capacity of the induction motors for railway service (in 500 H. P. to 750 H. P. capacity) greatly exceeds that of the series motors. Thus the maximum horse-power of the New York Central locomotive is about 3100 H. P. or 40 per cent. in excess of the nominal rating, while the overloads on the motors themselves is probably limited to about 100 per cent., by considerations of commutation and heating. The pull-out torque for induction motors of this size is six to seven times full load torque, and this overload capacity is attained without any special liberality of design. The pull-out attained in stationary practice should not be confounded with that possible for traction work.

With regard to mechanical structure, the induction motor, with its compact design, its windings encased in hermetically sealed tubes, and its collector rings instead of commutator, presents a much more rugged character than the series motors of the continuous current or one-phase type.

Speed Control.

Both with direct current and three-phase motors, the economical running speeds are limited to two or three; and all intermediate speeds are obtained only by rheostatic connections. Instead of connecting four direct current motors in series, then two multiple groups of two in series, and then four in parallel; three induction motors may be connected in cascade, then two in cascade, and

then two or three in multiple — in both cases there running speeds being obtained, and the same amount of power saved.

In the cascade or concatenation control, the secondary of the first motor is connected to the primary of the second motor, and the secondary of the second motor to the primary of the third motor, and the secondary of the third motor is connected to the rheostat. The speed under these conditions will correspond to the total number of poles in the cascade. Thus, if at 25 cycles, the motors in concatenation have 4, 6, and 10 poles, each will run at 150 revolutions per minute.

Without going into a theoretical discussion of this control, I should like to point out the absurdity of the objection that with cascade control, only a fraction of the equipment is used at the higher speeds — the whole number of motors only being used at starting. It is true that with the series parallel control all the motors, two or four, are continually in service, and that with concatenation control one or two motors out of three may be cut out for the highest running speed. But when a series motor is operating at the maximum speed it is underloaded to a marked degree. Thus, reverting to the New York Central locomotive, we find that it develops only 960 H. P. at 60 mph., or 44 per cent. of the nominal rating. The three-phase locomotive at the highest speed may only utilize 33, 50 or 67 per cent. of its aggregate capacity, but it does so by segregating the output to a fraction of the total *number* of motors, instead of utilizing only a fraction of the *capacity* of each. In both cases the result is identical, but the method is different.

Constant Speed Characteristic for Railway Work.

On account of the enormous development of electric railway work in this country in the field direct current, and on account of the standardization of apparatus in that line, the average technical man is apt to think that no other motor but the series type is suited to the requirements of traction. This point of view is distinctly provincial, and can only be eradicated by intelligent discussion of the merits of other systems. Let us briefly consider some points on the question of the speed characteristic for railway work.

In urban service where the greater part of the time is occupied in starting and stopping, and where the runs are so short that the maximum speed is of little consequence, the series motor presents

an admirable solution. But, as the distance between stops is lengthened and trunk line conditions are approached, the time consumed in accelerating is relatively small, and a motor which will maintain a given speed independent of gradients is much more effective from the point of view of the railroad operator. A motor with inherent variable speeds is no longer necessary, and in fact of no distinct advantage. Of course, the competitor of the series motor must possess equal characteristics in overload capacity response without injury.

The traffic which can be handled over a given stretch of road will depend on the number of cars per train and the number of trains which pass over the line per day. The train-miles possible will depend on the schedule speed attained; so that if a predetermined schedule can be maintained, the service capacity of the tracks will be increased. With the series motor, a drop in speed is inevitable if the train weight is increased by the addition of cars, or if a grade is reached. The additional tractive effort required in either case can only be obtained at a lower speed. The induction motor responds to the demands of heavier trailing load and of grades, without appreciable drop in speed, since the slip, even at five times normal full load torque, is only about 10 per cent. The advantage of the three phase motor in this respect is unquestioned.

It is claimed, however, that if the train is to run at the same speed on grade and level, the power required when running on the grade will be correspondingly greater, and that the peaks occasioned by these conditions will be excessive, and the load factor very low. We all admit that a poor load-factor is not conducive to economy, not only on account of the poorer efficiency of the generating and converting units at fractional loads but also on account of the fixed charges being independent of the output. But it must not be assumed that the constant speed characteristic of the three phase system will result in more unfavorable load fluctuations than any other system. These fluctuations will of course depend on the time table and the profile, but there are three considerations that should be borne in mind. First, for heavy grades, say between 0.8 per cent. and 1.5 per cent. the lowest or intermediate speed may be used, and the power required reduced correspondingly. Second, the power required for ascending the lighter grades generally will not exceed the power required

for accelerating. For example the power required to accelerate a 300 ton train on the level at 0.56 miles per hr. per sec. is the same as that required to drive the train at 70 m. p. h. on a 0.34 per cent. grade or at 40 m. p. h. on a 1.7 per cent. grade. Now since the whole system is designed for the maximum demands, occasioned by the heaviest trains accelerating, no additional investment in copper conductors or machinery is necessitated by the constant speed and variable power characteristics of the three-phase motor, nor will the peaks occasioned by grades on the average exceed the peaks due to the trains starting. Third, another influence which tends to equalize the load variations is the recuperation feature, which is unique with the three-phase system. The recuperation of energy will form the topic of the next paragraph, and we shall merely point out here that with a fair density of traffic, the excess of power required by the ascending train will be furnished by the power generated by the descending train in the neighborhood.

The Value of Recuperation.

It is an inherent characteristic of the induction motor that when the torque becomes negative and the speed rises above synchronism, it acts as a generator, returning energy to the line. This feature is utilized in the three-phase system to conserve the energy which would otherwise be wasted when running on down grades and during braking.

The amount of recuperation possible on down grades depends on the degree of the gradient; if the negative tractive effort due to the grade is just equal to the train resistance, the motors will merely run currentless; but if the negative grade resistance exceeds the train resistance, the motors will attain a negative slip and recuperate energy. The kilowatt-seconds recuperated will depend upon the speed and the length of the grade.

To recuperate during retardation (if there are only two running speeds) the controller is set for the cascade connection; then, during the period in which the speed changes from its initial value to synchronous concatenated speed, the motors will generate energy at a rate depending on the rate of braking.

Recuperation with induction motors is thus effected automatically and without any complicating devices. The per cent. of the available kinetic energy of the moving train that can be recuperated during coasting or braking depends upon the train resistance

and the efficiency of the motors, and it is difficult to state this in a generalization. The amount of the available recuperated energy that can be utilized by trains in the vicinity running on the level or on up-grades, will depend on the line losses between the point where the energy is liberated and the point where the energy is utilized. With a fair degree of traffic, 80 per cent. to 90 per cent. of the available recuperation can be made use of for train propulsion. The practicability of the recuperation feature on lines with heavy grades has been established beyond question by tests and four years' operating statistics.

The final value of recuperation lies in the fact that the watt-hour per ton mile consumption is reduced from 10 per cent. to 40 per cent., varying with the degree of the various influences present. The lower watt-hour consumption thus reduces the size of the generating station necessary for the given traffic, and the transmission and transforming apparatus. This result not only decreases the cost of producing energy, but also diminishes the fixed charges on the investment for the electric equipment.

Two Overhead Trolley Wires.

Perhaps the objection requiring the most serious consideration that is urged against the three-phase system is the use of two overhead working conductors. It is claimed that this arrangement costs more, and that it entails difficulties in operation at switches and cross-overs.

It is almost axiomatic that a three-phase distribution for the same voltage, power transmitted and allowable losses, requires only 75 per cent. as much copper as the single-phase system; so that the additional investment required for the suspension and insulation of the two wires will be compensated by the saving in weight of copper.

In point of operating cost, if we assume the same initial cost for both the three-phase and single-phase overhead systems, the fixed charges will be about the same. In the item of repairs, the material will naturally be greater for two wires than for one. But the heaviest charge for repairs and maintenance is the labor item of periodical inspection, which will be the same in both systems per mile of track, since the same crew can look after two wires equally as well as one.

But, even if the cost of repairs to the line equipment was greater,

its influence would be small, since the major part of the total cost of repairs is comprehended in the repairs to rolling stock, as is shown by past statistics on elevated, subway and interurban roads. and this item is very much smaller in the three-phase system on account of the more rugged construction of the motors, and the absence of a commutator.

In regard to operation difficulties at switches and cross-overs, experience has shown, on the Valtellina line and in the Simplon tunnel, both of which present complicated switching yards, that the design difficulties of the overhead construction have been solved. The two wires are suspended from a single support, and the two contacts of the current collector are also mechanically comprehended in a single structure. This subject need not be discussed in a speculative theorizing way, since the apparatus has passed the experimental stage, and has conclusively demonstrated its merits by years of operating results.

SUPPLIES FOR ENGINEERING TRIPS.

By WILLIAM NEWBROUGH.

Thinking it might be of interest to some readers of the QUARTERLY I furnish below a copy of my list of supplies for an engineering trip. I keep this list in my card index and when starting glance through it and take with me the ones desired. Some of the articles may seem peculiar, as, for instance, guns and fishing rods, but frequently when going into a game country they come in handy.

After looking over this list, be the trip for one day or three months, I can rest assured I have forgotten nothing. Certain articles may of course be omitted or added in accordance with individual ideas or requirements.

Bed. — Blankets, quilts, pillow, cover, bedrope.

Clothes. — Buttons, cap, collar buttons, comb, chamois underclothes, cuffs, collars, gloves, handkerchiefs, German socks, German sock overshoes, muffler, mosquito netting, needles, neckties, overalls, overcoats, overshoes, shirts, shooting coat, shoes, soap, socks, suits, smoked glasses, thread, underclothes, towels, hair brush.

Camp Outfit. — Axe, axle grease, baling wire, butcher knives, clevises, cups, collar pads, dish rags, Dutch ovens, dish pans, forks, grindstone, gunny sacks, hammer, hatchet, hay, horse blankets, harness, harness tools, halters, large forks, large spoons, knives, meat saw, monkey wrench, plates, pots, rope, spoons, stove, soap, tin buckets, kettles, towels, seamless sacks, skillets, tents, water jug, water bucket, wagon cover, wash basins, whips, saddles, saw, straps, wagons, horseshoes, pincers, rasps, pick, shovel, bar.

Instruments. — Adjusting pins, transit, plumb bobs, plumb bob string, transit wrench, magnifying glass, tripod, solar, field glasses, hand level, level, level tripod, rod, stadia rods, targets, target springs, chain, steel tapes, linen tapes, pins, cold chisels, timber scribes, carpenters' pencils, chalk, tally boards, tally counters, pedometer, stone hammer, thermometer, barometer, spring balance, compass, compass tripod, pocket compass.

Stationery, Books, etc. — Henck, traverse tables, Trautwine, Searle, Shenck, Coal and Metal Miner's Pocket-book, Hodgman, Kent,

Kidder, new note-books, old note-books, maps, blue-prints, thumb-tacks, india ink, erasers, water colors, colored pencils, drawing pens, paper, profile paper, tracing cloth, blue-print paper, crow-quill pens, writing pens, note paper, dividers, compasses, rectangular protractors, pencils, emery cloth, envelopes, postage stamps, triangles, straight edge, colored inks, stylographic pen, ephemeris, scales.

Photography. — Camera, tripod, roll-holder, plates, plate-holders, dust brush, focus cloth.

Provisions. — Flour, sugar, baking powder, coffee, tea, condensed milk, potatoes, tomatoes, corn, canned peas, canned pork and beans, canned fruit, cheese, butter, bread, eggs, ham, bacon, salt side, fresh meat, onions, pickles, canned jam, syrup, sardines, canned meats, canned salmon, fresh fruit, salt, pepper, mustard, cabbage, carrots, beets, oatmeal, sweet potatoes, squash, vinegar, matches.

Sundries. — Shot gun, shells and rod; rifle, shells and rod; fishing rod, reel, fly-hooks, flies, leader box, fishing shoes, waders; money, check-book, tobacco, cigars, pipes, matches, quinine, alcohol, hypodermic syringe, pills, cascarets, glycerine.

ABSTRACTS OF RECENT MINING DECISIONS.*

DAMAGES. FAILURE TO PRODUCE MAPS.

In an action by the lessee of a mine against the lessor for damages for eviction and for the value of ore taken, and where the veins included within the description were in dispute, and the lessor failed to produce its office map, referred to in the description, the court held that such failure to produce the map, warranted the presumption that the map would show that the lessees' contention was correct.

Isabella Gold Min. Co *v.* Glenn (Colo.), 86 Pac. 349.

ADVERSE PROCEEDINGS. PROOF OF TITLE.

The United States statutes provide that in an adverse suit, if the title to the ground in controversy should not be established by either party it should be the duty of the jury to so find, and that judgment be entered according to the verdict. The object of this statute was said to be, to provide that in the case of a failure of proof of title, for an adjudication that neither party was entitled to the property and that the applicant could not then go forward with the proceedings in the land office simply because the adverse claimant had failed to make out his case, if he himself had failed.

Brown *v.* Gurney, 26 Sup. Ct. 509.

RIGHT TO RAILROAD SIDINGS.

The constitution and statutes of the state of Pennsylvania make all railroads, public highways and railroad companies common carriers; and under the constitution and statutes the court of that state held that the owner of coal-mining property adjoining the right of way of a railroad was entitled as a matter of right, to connect the switch tracks built on his own land with the tracks of a railroad company in order to facilitate the loading and shipping of coal.

Olanta Coal Min. Co. *v.* Beech Creek R. Co., 144 Fed. 150.

RIGHTS TO SWING CLAIM DURING LOCATION.

The rules as to the location of mining claims do not exclude other prospectors from the area of the claim absolutely, but only prohibits the acquisition of rights within the area which would interfere or conflict with the right of the first discoverer to swing his claim so as to lay it along the lead after his exploratians demonstrate its strike. The effect of this is that a subsequent explorer would go into such area at his peril. But the result would be that after the first discoverer had completed his work and located his claim the junior discoverer ought to be secure in any location made by him in the mean time upon other portions of the area not in conflict with the rights of the first discoverer.

Helena Gold &c. Co. *v.* Baggaley (Mont.), 87. Pac. 455.

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* Prepared for the SCHOOL OF MINES QUARTERLY by J. W. Thompson, Attorney-at-Law, Indianapolis, Indiana.

Failure to Perfect Location.

The failure of the first claimant to complete his location after posting his preliminary notice inures to the benefit of a junior locator whose claim is in conflict with such older claim, when the inchoate right acquired by the discoverer and the posting of the notice never became fixed by a completion of the location.

Helena Gold &c. Co. *v.* Baggaley (Mont.), 87 Pac. 455.

Extra Lateral Right.

The possession of the surface of a mining claim is the possession of a vein or lode having its apex within the surface lines of the claim; although extending downward, such vein may pass beyond the vertical side lines of the claim, and will support an action of trespass for the removal of ore from such vein beneath the surface of an adjoining claim.

Montana Mining Co. *v.* St. Louis Mining etc. Co., 147 Fed. 897.

Liability of Innocent Trespasser.

In an action of trespass for taking ore from the claim or vein of another it makes a difference whether the person taking such ore was an innocent or a wilful trespasser. An innocent trespasser is liable under the law for the actual value of the ore taken less the reasonable cost of extracting the ore, raising it to the surface, transporting it to the mill, and reducing or milling it. But he is not entitled to claim any mitigation of damages for money expended in the running of levels, sinking of shafts, or development work, except to the extent actually necessary to the extraction of the ore in controversy. Neither can an innocent trespasser charge for any extraordinary expenses to his plant, or any wages to any persons except those actually employed and engaged in extracting, transporting and milling of the ore in question.

Montana Mining Co. *v.* St. Louis Mining etc. Co., 147 Fed. 897.

Safety of Working Places.

An employer is always required to furnish a safe place for his employees to work. But a higher degree of care is required in this respect of an employer whose employees are underground with scant means of escape, than in cases where they are in a position to escape readily.

Williams *v.* Sleepy Hollow Min. Co. (Colo.), 86 Pac. 337.

Negligence of Employer. Effect of Miner's Contract.

The owner of a mine is not liable for injury to a miner occasioned by falling material from the roof of the mine, where the injured person was an experienced miner and where it was a part of his duty to properly and securely prop or support the roof of the mine, and where it appeared that such injured person knew that the mine roof was not properly supported. But under the agreement between the coal operators and the United Mine Workers of America, which was made a part of the miner's contract, it was decided that when the miner called the attention of the pit boss to the roof at the place where the accident subsequently occurred, it then became the duty of the operator of the mine to double timber as the situation required, and that from that time on the responsibility for the safety of

the roof rested on the mine owner, and that he was properly held liable for negligence in this respect.

Cook *v.* Smith-Lowe Co., 109 N. W. 798.

Duty to Inform Employe of Danger.

It is the duty of the owner of a mine to furnish the miners a safe place in which to work; and where a miner was ignorant of the danger of the place in which he worked, and could not by ordinary care have discovered such danger, it was said to be the duty of the employer to inform him of the situation; and in the absence of an official of a higher position, this duty devolved upon the foreman, under whom the miner was working. In states where the statute provided for the appointment of a mine boss, it is his duty to see that the place where the miner works is reasonably safe, and such a mine boss is not a fellow servant of the miner.

Low Moor Iron Co. *v.* La Bianca (Va.), 55 S. E. 532.

Assumption of Risk by Employe.

The rule requiring the owner of a mine to use reasonable diligence to furnish a reasonably safe place for the miners to work has no application to the miners or persons whose duty it is to make dangerous places safe. Such persons necessarily assume the additional hazard of the particular employment.

Kellyville Coal Co. *v.* Bruzas (Ill.), 79 N. E. 309.

METALLURGICAL ABSTRACTS.

By WILLIAM CAMPBELL.

Aluminium: E. K. Judd, *Min. Ind.*, 14, 11. Reviews the production, market and prices for 1905. Discusses the production and plants of the European companies and the progress in the metallurgy of aluminium. Betts Process: U. S. Patent, No. 795, 886. Soldering, the metal must be heated to 660 degrees or 200 degrees higher than that required by brass before solder will adhere to it. A solder recommended is: Al 1; phosphor-tin 1; zinc 11; tin 29. Jackman has patented a solder containing tin 64; zinc 30; lead and aluminium each 1 part. An autogenic method has been patented by Tomellini, U. S. Patent, No. 783, 332. Plating on aluminium. Creswick and Shaw first apply a thin coat of tin. The difficulty of plating lies in obtaining a clean surface. Several baths are quoted from *La Metallurgie*, December 7, 1904, p. 2,311. Aluminium alloys. Guillet in *Revue de Metallurgie*, II., 8, gives tests on aluminium bronzes. The 10 per cent. Al alloy gives an E. L. of 24,032 lbs. per sq. in. as cast; while 49,340 lbs. per sq. in. was obtained from cold-worked material containing 92.23 per cent. copper.

Antimony: E. K. Judd, *Min. Ind.*, 14, 23. Gives the production, market and progress in the Metallurgy of Antimony for 1905. Abstract of Betts' work on the electrolysis of antimony solutions. MacArthur process applied by the Dominion Antimony Company in Nova Scotia to antimony gold ores. Antimony alloys. Specifications for babbitt metal run:

German R. R. tin 83.3 per cent.; antimony 11.1 per cent.; copper 5.6 per cent.

U. S. R. R. tin 88.9 per cent.; antimony 7.4 per cent.; copper 3.7 per cent.

See also *E. and M. J.*, 81, 48.

Arsenic: Min. Ind., 14, 29. Gives the source of arsenic both in this country and abroad. The Everett plant of the American Smelting and Refining Company treats the arsenical pyrite from the Monte Cristo mines of Washington. Arsenic is produced at the Washoe smelter, Anaconda. The leading source of arsenic is the Reicher Trost mine in the Breslau district, the Freiberg metallurgical works giving the main output of arsenic products. The arsenopyrite of Cornwall and Devon was formerly the main source of arsenic but the production has fallen off enormously since 1900.

Bismuth: Min. Ind., 14, 52. Johnson, Matthey and Co., London, seem to control the production. All of our bismuth is imported and the price has risen from $0.75 in 1896 to $2.14 in 1905. The ordinary methods of bismuth smelting are described in *Min. Ind.*, VIII., 58.

Chromium and Chrome Ore: E. K. Judd, *Min. Ind.*, 14, 71. Gives the production of chrome ore, at home and abroad. Ferro-chromes with 50–60 per cent. chromium were made from chromite by reduction with charcoal in brasqued crucibles. Are now made in the electric furnace.

Copper: W. R. Ingalls, *Min. Ind.*, 14, 110. Gives the production of copper to end of 1905, under the heading of Lake, electrolytic and casting or pig copper. There are eight important electrolytic refineries in this country. The Nichols Copper Co., Laurel Hill, L. I., the De Lamar works at Carteret, N. J., the Raritan works at Perth Amboy, the A. S. and R. Co's. works at Perth Amboy and the Balbach works at Newark, N. J., are the largest and are in the vicinity of New York. Besides these are the Baltimore works, those at Great Falls, Mont., and Tacoma, Wash. Review of copper mining in the U. S. and abroad.

Progress in the Metallurgy of Copper in 1905: L. S. Austin, *Min. Ind.*, 14, 151. Treats first with the copper alloys, Guillet's work on bronzes in *Revue de Metallurgie*, II., pp. 97–566; and L. Addick's paper on the effect of impurities on the conductivity of copper, *Trans. A. I. M. E.*, XXXVI., p. 18. Under the heading of smelting practice, describes the works of the Michigan Smelting Co. (White, *E. and M. J.*, § 79, p. 842). Abstracts a paper by C. H. Fulton and T. Kuntzen *Trans. A. I. M. E.*, XXXV., 326, on Matte Smelting at Rapid City, S. D., and another by Pearce on Cleaning Reverberatory Furnace slags as practiced at the Boston and Colorado plant, Argo, Colo., *Trans. A. I. M. E.*, XXXVI., p. 89. Next follows an account of the smelting works of the Tennessee Copper Company; the Cananea smelting plant (*Mining. and Scientific Press*, Nov. 25, 1905); the Tacoma smelting works; copper smelting at Kedabeg, Russia (*Trans. I. M. and Met.*, XIV., 497). Abstracts Gibb and Philp's paper on constitution of mattes produced in copper smelting, *Trans. A. I. M. E.*, XXXVI., 665, which shows that cuprous and ferrous sulphids will combine to form a compound 5 Cu_2S, FeS or white metal which enters into the composition of all mattes.

Copper Deposits of New Jersey: N. S. Keith, *Mining Magazine*, XIII., 468. At Arlington, Bound Brook and Pahaquarry copper occurs as oxide, carbonate and sulphide in sandstone. and is usually related to the intrusive trap. At Bound Brook the method of extraction is on Wilfley tables; at Pahaquarry the material is to be crushed to 60 mesh and passed through two patent furnaces, which reduce the copper to the metallic state. The copper will then be concentrated in tables, melted and cast.

The Copper Mines of Japan: E. and M. J., 81, 1041. The two largest are the Ashio, producing 7,000 tons refined copper a month, and the Besshi 6,000 tons. The Ashio ore is entirely sulphide, running 4 per cent., is concentrated to 15 per cent., which is smelted. The matte is converted and the blister electrolytically refined.

The Mining Industry of Japan: W. J. Johnson, *Min. Mag.*, XIII., 23. Gives an account of the mining industry, with views of the Shisaka smelting plant.

Mineral Production of Norway: E. and M. J., 81, 1057. The Sulitjelma copper works, east of Bodö, are being enlarged. They produced between 400 and 500 tons of copper in 1905. The Alten, Röros and Lyngen smelters, are running. The Bosmo, Kjöli & Killingdal mines, are producing about 70,000 tons pyrite. At the Evje nickel works 190 tons nickel-copper matte were produced. Seven and a half tons of silver were produced from the Kongsberg mines.

Pyritic Smelting: R. Sticht, *Metallurgie*, III., 105, 149, 222, 256, 265, 386. Discusses the question of pyritic smelting very thoroughly, with special reference to work done at Mt. Lyell.

Pyritic Smelting: R. C. Alabaster and F. H. Wintle, *Trans. I. M. and Met.*, XV., 269. Describe the work at Ducktown, Tenn., at the Tennessee Copper Co.'s and Ducktown Sulphur, Copper and Iron Co.'s smelters.

Pyritic Smelting Without Coke: L. T. Wright, *Min. and Sci. Revs.*, XCII., 237. Gives tables showing relation of coke consumption and grade of matte with cold blast, also percentage coke, percentage copper in water and tons smelted with hot and cold blast. Shows what are the limiting factors for smelting without coke.

Blast-furnace Charging: I. John, *E. and M. J.*, 81, p. 126. Describes the method in use at the Cia. Metalurgica de Torreon, Mexico, with drawings.

A combined Siphon-Spout and Matte-trap: H. Harris, *E. and M. J.*, 81, 178. Describes and gives drawings of siphon-spout which has been used in smelting base lead ores. It consists of a L-shaped cast-iron base in communication with tap hole. It has a water jacket partition which divides the upper part into two portions. The slag flows from one, the matte from the other.

The Baggaley Pyritic-conversion Process: E. and M. J., 81, 574. The process aims to treat low-grade pyritic copper ore by smelting only (avoiding water concentration with its high losses of mineral) and producing originally a low grade matte. This is enriched by stages to blister copper in a basic lined converter, the silica flux being introduced as siliceous ore. The article contains details of work done at the Pittsmont smelter, Butte, Mont.

A New Method of Smelting Butte Ores: W. A. Heywood, *Min. and Sci. Press*, XCII., 281. Describes the Baggaley process as used at the Pittsburg and Montana Copper Co., Butte, Montana.

Recent Improvements at Anaconda: L. S. Austin, *M. and Sci. Press*, XCII., 140. The plant was described in *M. and Sci. Press*, LXXXIV., 202, just after completion. This article shows the line of development and has excellent photographs of the blast furnace and reverberatory furnaces.

Coal-Dust Firing of Reverberatory Matte Furnaces: S. Sörensen, *E. and M. J.*, 81, 274. Gives details of experiments carried on at Highland Bay Smelter, Murray, Utah, with curves and drawings. The results of a two months' test showed that the coal-dust fired furnace smelted 30 per cent. more calcines and used 24 per cent. less coal per ton of calcines smelted.

The Mathewson Blast Furnace: E. and M. J., 81, 370. Gives figures and description of new blast furnace. It consists of a narrow and long shaft in the bottom of which are arranged a plurality of crucibles.

New Blast Furnace for the Matehuala Smelter: E. and M. J., 81, 1133. The National Metallurgical Co.'s smelter at Matehuala, Mex., put into operation last year is being enlarged by the addition of a 42 ×

160 inch furnace of 250–300 tons capacity. Giroux hot blast top. A photo shows the furnace assembled.

The De Lamar Copper Refinery: Pufahl, *E. and M. J.*, 81, p. 73. Describes the refinery at Chrome, N. J.

Recent Copper Smelting at Lake Superior: L. S. Austin, *E. and M. J.*, 81, p. 83. Describes the Michigan Smelter, giving details as to furnaces, treatment of charges in the reverberatory and the smelting of the reverberatory slag.

The Perth Amboy Plant of the American Smelting and Refining Co.: O. Pufahl, *E. and M. J.*, 81, 169. Describes the one-smelting, the electrolytic copper refining, the manufacture of copper sulphate, lead refining and the gold and silver parting.

The Nichols Copper Works: O. Pufahl, *E. and M. J.*, 81, 314. Ores are smelted in two water-jacketed Herreshoff furnaces, giving a 40–60 per cent. Cu matte. Mattes are melted down in a cupola and converted. There are 4 sets of three converters each. Charge 2–6 tons. Refining. 90 per cent. of the raw material of these works is blister. This is melted down and partially refined in 10 reverberatories. Metal is poured by Herreshoff casting table with 9 anode iron moulds. Series system used. Eight reverberatories for melting down cathodes, charges 30–45 tons. Most of the product is wire-bars.

The Determination of Matte: J. P. Walker, *E. and M. J.*, 81, 852. Gives various formulæ used in calculating the grade of matte to be expected from a calcine of a given percentage of copper and sulphur.

Treatment of Speiss and Speissy Blister Copper at the Okerhutte, Germany: Hühn, *Mining Mag.*, XIII., 57, *trans. from Glück Auf.*, 1905, p. 1165. Rammelsberg ores divided into copper ores, mixed ores and lead ores. Copper ores are smelted at the Okerhütte and lead ores at Juliushütte and Sophienhütte. During the melting a speiss running 52 per cent. Cu, 35 per cent. Pb, 2.75 per cent. As, 3.34 per cent. Sb, 1.38 per cent. S, and another of 26 per cent. Cu, 16.7 per cent. Pb, 11 per cent. As, 13,5 per cent. Sb, 4.13 per cent. S, 22 per cent. Fe are formed. The old method of treatment was in a reverberatory and consisted in slagging off the impurities. Treatment in the blast furnace with 80 per cent. slag and 30 per cent. rich copper ore, was unsatisfactory. The present method consists of a slow roast in a reverberatory followed by a smelt in the same furnace which has two tuyeres to increase oxidation. The copper thus obtained is granulated and undergoes the sulphuric acid treatment. See also:—

On the Treatment of Speissy Blister Copper: G. Kroupa, *O. Z. Berg. und Hüttenwesen*, LIV., pp. 73, 84.

Gold and Silver: F. Hobart, *Min. Ind.*, 14, 217. Gives the production of gold and silver; mining and other information.

Progress in Gold-Ore Treatment during 1905: A. James, *Min. Ind.*, 14, 268. Takes up the subject of Regrinding, Amalgamation, Filter-pressing, Slimes Treatment, West Australian Practice, African Practice, Mexican Practice and Zinc-Box Work and Cleaning Up.

Gold Dredging in 1905: J. P. Hutchins, *Min. Ind.*, 14, 275. Deals with the expansion of dredging, variation in practice and design, etc.

Hydraulic Mining in California: J. P. Hutchins, *E. and M. J.*, 81, 939. Deals with the antiquity of placer mining and the invention of hydraulicking. The debris problem is taken up and the present status discussed. The paper has several excellent photographic illustrations showing the Bowman Dam and the North Bloomfield Mine.

Development of Placer Gold-Mining in the Klondike District, Canada: J. B. Tynell, *Trans. I. M. E.*, XXXI., 556. Describes the work of placer mining in the Klondike with numerous illustrations of flumes and sluices.

Hydraulic Mining in a Cold Climate: J. P. Hutchins, *Min. and Sci. Press*, XCCI., 361. Describes hydraulicking in Klondike with a description of the various gravels. Two photographs show the monitors at work.

Progress in Gold Milling in 1905: R. H. Richards, *Min. Ind.*, 14, 289. Amongst other things deals with the regrinding of sands (*Trans. I. M. and Met.*, XIV., p. 3), fine grinding of gold ores with special reference to the Tube Mill (*Mining Reporter*, LII., pp. 240, 287, 307, 333), practice at Camp Bird (*E. and M. J.*, 79, 850), the treatment of refractory sulphides at the Cassilis mine, Victoria (*Trans. I. M. and Met.*, 14, 541). Mill practice on the Rand (*Mining Mag.*, XI., 401; XII., 173). Ore milling at Kalgoorlie (*E. and M. J.*, LXXX., p. 4): Mill practice of Western Australia (*Trans. I. M. E.*, 28, p. 585 and *Mining and Sci. Press*, XCI., 366). Hydraulicking is taken up at length, and then gold dredging.

Good Mill Construction: M. and Sci. Press., XCII., 22. An account of the Bustos mill at Guanajuata, Mexico with photographs and drawing illustrating construction.

Stamp Milling in Northern California: A. Del Mar, *Min. and Sci. Press*, XCII., 145. Describes the Edel mill with its quadruple discharge batteries.

A Modern Stamp Mill: Min. and Sci. Press, XCII., 200. Gives drawings of a 20 stamp mill erected at Murray, Idaho, for the Golden Reward Mining Co.

Cyanidation during 1905: C. H. Fulton, *Min. Ind.*, 14, 281. Describes the application to silver ores in Mexico; the Merrill filter-press; the Moore process; the Ogle continuous filter; cyanidation of cupriferous ores; sodium and potassium cyanide; and then gives a short review by states.

The Stamp Mill and Cyanide Plant of the Combination Mines Co., at Goldfield, Nevada: M. R. Lamb, *E. and M. J.*, 81, 1236. Consists of 20 stamps, copper plates 2 Bryan Mills, one Wilfley table, 7 Frue vanners, 3 Wilfley slimers, one Abbé 12 ft. tube mill, 3 Frenier sand pumps, cone classifiers, 8 filling tanks, 8 leaching sand tanks together with slime-settling, agitating and storage tanks and a Butters slimes filter box.

Milling vs. Smelting in the Treatment of Tonopah-Goldfield Ores: F. L. Bosqui, *Min. and Sci. Press*, XCII., 217. Compares figures obtained from Selby Smelting and Lead Co., with those of the combination mill and it is more profitable to mill ore up to $6oo.

Mining and Metallurgy in El Oro, Mexico: H. E. West, *Mining Mag.*, XIII., 357. Describes the occurrence and mining. The ore is stamped through 30 mesh, plate amalgamation, sizer cones, sands to 3 Krupp tube mills and classified. Slime treatment by cyanide agitation. Sands in ordinary way. Mercuric chloride and lead acetate are used on account of the silver contents of the ore.

The Peregrina Mill, Guanajuata: F. J. Hobson, *E. and M. J.*, 81, 943. Will consist of 2 Gates crushers. Twenty challenge feeders to deliver to ten 10-stamp batteries. Crush wet through 40 mesh. Amalgamated plates to Wilfleys of which there will be 20. Tailings to flow to a series of cone separators. Coarse sands reground in tube mill. Material is then separated into sands and slimes. Slimes are to be treated in cyanide plant by air agitation and decantation; the sands charged and discharged by the Blaisdell method.

Metallurgical Development on the Rand: G. A. Denny and H. S. Denny, *Min. and Sci. Press*, XCII., 364. Show the great increase in extraction by use of fine grinding and filter pressing.

Tube Milling on the Rand: Mining Magazine, XIII., 409. The process is employed on the New Goch, Glen Deep, Meyer and Charlton, Angelo, Driefontein, Treasury, Knight's Deep and Robinson Deep. The paper includes data of work done, taken from *South African Mines*, February 10 and March 10, 1906.

Progress of the Gold Mining Industry of Western Australia: W. Burrell, *Mining Mag.*, XIII., 381. The Ivanhoe has 9 ball mills, 15 Edwards roasters, 7 Wheeler pans, etc. The great Boulder Perseverance, the South Kalgurli, Oroya Brownhill and other Kalgoorlie mines are making good returns.

Ore Treatment at the Kalgurli Gold Mines: R. Allen, in *Monthly Journal of Chr. Mines of West Australia;* abst. *Mining Mag.*, XII., 423. Gives an account of the ore treatment with a chart. Ore is broken, passes through one of 9 Ball mills run dry. Dust to bromo agitation vat, fines to 15 Edwards roasters, 2 mixers, hydraulic classifiers, coarse to 17 Wheeler pans, giving concentrates which pass through Berdan pan to clean amalgam. Slimed product treated by agitation and filter presses.

The South Kalgurli Co.'s System of Ore Treatment: A. C. Claudet, *E. and M. J.*, 81, p. 129. The new plant treats 230 tons a day by dry crushing, roasting, grinding and amalgamating, agitating with cyanide and filter pressing. A diagram of the treatment is given.

Grinding Pans Versus Tube Mills: E. S. King, *Mining Mag.*, XIII., 411, taken from *New Zealand Mines Record*, Dec. 16, 1905. Gives record of experiments with two pans and one flint mill at the Ivanhoe mine, Kalgoorlie, which show that the pans do the best work for this particular ore.

Slime Treatment at Mount Boppy: J. M. Bridges, *Australian Mining Standard*, Feb. 28, Mar. 7, 1906; abst. *Mining Mag.*, XIII., 414. The Mount Boppy mine is in the Cobar district, N. S. W. The oxidized ore treated in a 40-stamp battery and passes over amalgamated copper plates. Pulp separated into slimes and sands. Slime treated by agitation and passed through two 3-ton Dehne presses. Three zinc boxes used to precipitate. The sulphide ore treated in 20-stamp battery, copper plates,

Spitzlutte, Wilfley table, Ivanhoe pan producing amalgam, Spitzlutte and a second Wilfley, etc. Separation of sands from slimes. Slimes treated with those of oxide plant. The KCN solution runs 0.04 per cent. and is raised to 0.12 per cent. in the agitators.

Mining and Metallurgical Methods of the Waihi Gold Mining Co., New Zealand: F. N. Rhodes, *Mining Mag.*, XIII., 15. Describes the occurrence and mining of the ore. The mill has challenge feeders, 330 stamps in 3 mills, slimes separated from sands, which pass through tube-mills, run over Muntz-metal amalgam plates, thence to sizers above Union and Wilfley vanners. A cyanide treatment follows. The raw concentrates are cyanided also with a yield of 95 per cent.

Occurrence and Treatment of Gold Ore at Bidi, Sarawak: T. C. Scrutton, *Trans. I. M. and Met.*, XV., 144. Describes the occurrence and mining of the ore, which is (1) oxidized siliceous, (2) shaly and refractory, (3) arsenical. The refractory ore is roasted in lumps and crushed along with the siliceous material and cyanided. The arsenical ore is also roasted before treatment with cyanide. Further details are given in :—

The Occurrence and Extraction of Gold in Sarawak, Borneo: W. Hamilton, *Trans. I. M. and Met.*, XV., 185.

The Ammonia-Copper-Cyanide Process: E. Brereton, *Trans. Inst. M. and Met.*, XV., 433. Experiments show that under certain conditions cuprous potassium cyanide in an ammoniacal solution, is broken up with the liberation of an alkaline cyanide.

The Cyanide Treatment of Cupriferous Tailings by the Sulphuric Acid Process: W. S. Brown, *Trans. I M. and Met.*, XV., 445. Describes process applied to tailings from the Cobar Chesney Mine, Cobar, N. S. W., which consisted of first a dilute acid treatment whereby all the copper was dissolved and subsequently precipitated, then after washing, .8 per cent. lime was added and a cyanide treatment given.

A Wet Silver Mill: R. B. Brinsmade, *Mines and Minerals*, 26, 492. Describes the plant of the Combination Mining and Milling Co., Granite Co., Montana. Has a battery of 20 stamps, 12 vanners, which separate tetrahedrite from malachite. Tetrahedrite roasted in 2 Brückners with salt. There are 14 pans and 7 settlers.

Pachuca: H. E. West, *in. and Sci. Press.* To-day there are three centers of activity: the Real del Monte; the Santa Gertrudis and the San Rafael. There are no mills at the mines, the ore being treated in the town by an improved patio process. At the Progress there is an installation of Boss continuous process; at the Union a partial form of Barrel chlorination is used.

Iron and Steel: F. Hobart, *E. and M. J.*, 81, 48. A short review of the industry for 1905, will be found at length in *Mineral Industry*, 14, 319.

The Progress of the Metallurgy of Iron and Steel in 1905: Bradley Stoughton, *Min. Ind.*, 14, 346. Deals with the blast furnace, Bessemer process, open-hearth process, foundry practice and electric smelting. Pyrometers and alloy steels are also discussed.

The Early Use of Iron: B. H. Brough, *J. I. and S. Inst.*, 1906, I., 233. An exceedingly interesting paper on the early history of iron, its uses and manufacture in very early times.

Theory and Practice of Dephosphorization of Iron and Steel: E. Richarme, *Bull. Soc. de l' Ind. Minérale*, V., 1906, p. 83. Deals with the general idea of dephosphorizing and the determination of the amount of dephosphorization of slags by laboratory work. The third part considers the different methods used, the blast furnace, Rollet's method, Bell's method, puddling furnaces, Bessemer converter and Siemens-Martin furnace.

Chemical Action in the Acid Open Hearth Furnace: M. Deslandes, *Rev. de Met.*, III., 321. Takes into consideration the different elements C, Si, Mn, then S, P, Ni. The work deals with the period after fusion when the bath is covered with slag. The coefficients of distribution R per cent. in slag ÷ R per cent. in metal in function of carbon per cent. in metal and silica per cent. in slag are studied for the various elements.

The Influence of Nitrogen on the Properties of Iron and Steel: A. Pourcel, *Rev. Univ. des Mines*, XV., 229. Discusses the works of Braune and Tholander.

Nitrogen in Steel: E. and M. J., 81, 416. The presence of nitrogen which combines with the ferrite causes brittleness. 0.07 per cent. nitrogen renders low carbon steel brittle and causes a change of structure, whilst in steel with 1.15 per cent. C. this is caused 0.03 per cent. nitrogen. (See H. Braune, *Rev. de Met.*, 1905, 502.)

Preliminary Note on the Influence of Manganese on Iron: J. O. Arnold and F. K. Knowles, *J. I. and S. Inst.*, 1906, I., 106. Consists in an attack on the reliability of Léon Guillet's work on manganese steels. The authors describe their method of manufacture but the finished bars showed extreme variations in composition. The paper is well criticized by Harbord.

Brittleness and Blisters in Thin Steel Sheets: E. F. Law, *J. I. and S. Inst.*, 1906, I., 134. Describes the experiments from which the author concludes that oxidized steel will give rise to blistered sheets, whilst steel high in sulphur and phosphorus will cause brittleness in sheets.

Relation Between Type of Fracture and Microstructure of Steel Test-pieces: C. O. Bannister, *J. I. and S. Inst.*, 1906, I., 161. Cup fractures are obtained with homogeneous, minutely crystalline or granular steel; laminated fractures from steels containing slag lines or minute ghost-lines running across the specimen. In slag lines both manganese silicate and manganese sulphide occur. Crystalline fractures show a distinct relationship between the size of the crystals and microstructure of the steel.

The Effect of Copper in Steel: F. H. Wigham, *J. I. and S. Inst.*, 1906, I., 222. Shows that copper up to 0.25 per cent. is no disadvantage in the manufacture of the best class of steel wire.

The Molecular Change in Hardening: O. A. Böhler, *O. Z. Berg- und Huttenwesen*, LIV., 334. Deals with the transformations which steels undergo when they pass through their critical points and draws analogy to the freezing of brine solutions.

Cementation by Means of Gases: Metallurgie, III., 123. Iron containing C = 0.03 per cent. was cemented by various gases at temperatures from 600°C. to 1200°C. and the amount and depth of the carbonization carefully determined. The paper is illustrated by curves and photomicrographs.

The Burning, Overheating and Restoring of Steel: G. B. Waterhouse, *E. and M. J.*, 81, pp. 368, 414. Gives definitions of burning, overheating and restoring steel, quoting such authorities as Howe, Metcalf, Heyn, Stead, Stansfield, Harbord and others. Then goes on to show the effect of heat on the crystal size and the relation of size of crystals to mechanical properties. Discusses mechanical refining and finishing temperatures and heat refining.

Volume and Temperature Changes during the Cooling of Cast Iron: T. Turner, *J. I. and S. Inst.*, 1906, I., 48. The apparatus used consists of (*a*) the mould with test bar, (*b*) an arrangement for indicating changes of length in the bar, (*c*) the pyrometer. The paper contains numerous curves for irons varying from pure white to foundry.

On the Influence of Certain Elements on the Separation of Graphite in Cast Iron: F. Wüst, *Metallurgie*, III., 169. Cast iron containing 3.96 per cent. C was alloyed with tin, sulphur, phosphorus and different amounts of silicon were present. Tin has but little effect. At 0.6 per cent. S the graphite is reduced to a minimum even with 2 per cent. silicon present. Increase in phosphorus with 0.1 per cent. Si sends the percentage of graphite up to about 60 per cent. of total carbon.

Influence of Silicon, Phosphorus, Manganese and Aluminium on Chill in Cast Iron: E. Adamson, *J. I. and S. Inst.*, 1906, I., 75. Comes to the conclusion that silicon is not necessarily the cause of carbon coming down as graphite. Phosphorus reduces the percentage of combined carbon and the depth of the chill whilst for manganese the reverse holds good. Aluminium reduces the depth of chill and converts white iron into gray.

Equilibrium Curves of the System Iron and Carbon: H. von Juptner, *I. and S. Mag.*, XI., 377. Takes up the data of Mannesmann, Osmond, Roberts-Austen, Carpenter and Keeling and Wust, and plots equilibrium curves therefrom. Then by use of Rothmund's equation calculates the molecular size of the carbon dissolved in iron. In fluid iron the carbon molecule consists of 2 atoms.

Metals and their Ferro-Alloys used in the Manufacture of Alloy Steels: O. J. Steinhart, *Trans. I. M. and Met.*, XV., 229. Deals with nickel, chromium, tungsten, molybdenum, vanadium, etc., and gives manufacture, history, and commercial and statistical data.

Lead: W. R. Ingalls, *Min. Ind.*, 14, 358. Gives the production of lead and a general review of the industry. The four large producers of refined lead in the U. S. are the American Smelting and Refining Co. and its allied interests, Balbach's, the St. Joseph Lead Co. and the St. Louis Smelting and Refining Co. a subsidiary of the National Lead Co. Early in 1906 the U. S. Mining, Smelting and Refining Co. was organized to compete for the market. They have the controlling interest in De Lamar's Copper Refining Co. who have installed a lead refinery at East Chicago and use Betts electrolytic process. The Huntington-Heberlein process of desulphurizing ore by air-blast has been installed in the plants of the A. S. and R. Co.

Recent Improvements in Lead Smelting: H. O. Hofman, *Min. Ind.*, 14, 388. Refers to the work of Friedrich and Leroux on the constitution of lead sulphides (*Metallurgie*, II., 536) which proves the series to consist of PbS and Pb, for all of the alloys show the freezing of lead at 327°C. Under the heading of purchasing lead ores, the rates of the A. S. and R. Co. for the treatment of gold-silver-copper ores from Clear Creek, Co., Colo., for 1905 are given (*Mining Reporter*, LII., 11). The section on Smelting Lead Ores embraces abstracts on smelting vadaniferous ores, Smelting in Greece, Lead Smelting in China, Smelting in the U. S. with notes on the Perth Amboy, National, Helena, Murray, Arkansas Valley, Pueblo, Eilers, Philadelphia plants, and the works of the Federal Lead Company near Alton, Ill. (Pufahl: *E. and M. J.*, LXXXI., 169, 719, 797, 889, 985, 1034). Metallurgical furnaces, Borchers, *Metallurgie*, II., 393, 523. Under the heading of Smelting in the Blast Furnace, Warwick's paper on roasting (*Mining Magazine*, XII., 196) is abstracted, Lime-roasting of Galena, gives the substance of several papers on the subject, notably Borchers, *Metallurgie*, II., p. 1; Hutchings, *E. and M. J.*, LXXX., 726; Biernbaum, *E. and M. J.*, LXXX., pp. 535, 680. The Carmichael-Bradford process, *E. and M. J.*, 1905, 778; Savelsberg, *Min. Mag.*, XII., 391, and Ingalls, *E. and M. J.*, LXXX., 1067. The Bormettes process described by Loti, *Mining Mag.*, XII., 426, is mentioned. Under the heading of Speiss two papers by Hübner (*Gluck Auf.*, XLI., 6) and Huhn (*Ibid.*, XLI., 1165) deal with the refining of Speiss at Freiberg and Oker. Numerous papers on Flue Dust are given. The article ends with a section on electrolytic refining of base bullion in fluosilicate solution. The first paper by H. Senn (*Min. Mag.*, XII., 71) gives the results of laboratory tests. That of Whitehead (*Mines and Minerals* XXV., 285) describes the Betts process in use at the Canadian Smelting Works at Trail, B. C. The last by Betts (*Electrochemical and Metallurgical Industry*, III., 272) deals with the treatment of electrolytic slime.

The National Plant of the A. S. and R. Co.: O. Pufahl, *E. and M. J.*, 81, 718. Comprises four softening reverberatories, one 100 tons, one 80 tons, two 30 tons. The copper dross is smelted in a small reverberatory with galena and yields work-lead and lead-copper matte ctg. 35 per cent. Cu. The antimonial skimmings are worked up in the usual way. Cast-iron desilverizing pots last 200 charges. Use Howard stirrer and press; 12 Faber du Faur oil-fired tilting retorts are used, and yield argentiferous lead running 9.6 per cent. Ag. This is charged molten onto the cupel. The first skims from the refining furnaces go to the hard-lead blast furnace, the lithage is run in a reverberatory for second-quality lead. Sulphuric acid parting is used for the Doré bullion.

The Perth Amboy Plant of the A. S. and R. Co.: O. Pufahl, *E. and M. J.* 81, 169. Plant consists of 11 reverberatories, 3 blast-furnaces, 4 softeners of 60 tons, 1 of 80 tons, five 60-ton zincing kettles, five refining furnaces, 18 Faber du Faurs and 7 English cupels.

The East Helena Plant of the A. S. and R. Co.: O. Pufahl, *E. and M. J.*, 81, 797. These works turn out 1,500 tons base bullion and 200 tons copper matte a month. Roasting department has two lots of 8 reverberatories and 16 Brückners. Automatic charging for two rectangular blast furnaces of Eiler's type.

The Globe Plant of the A. S. and R. Co.: O. Pufahl, *E. and M. J.*, 81, 858. The plant produces 1,800 tons base-bullion and 200 tons matte per month. The roasting department consists of 15 reverberatory furnaces, 2 Brown O'Harras and 12 Brückners. There are 7 rectangular blast furnaces, from which matte and slag are tapped together and separated in settling reverberatories. (The roasting department of this plant has now a Huntington-Heberlein installation and the Brückners are idle.)

The Pueblo Smelters: O. Pufahl, *E. and M. J.*, 81, 889. The Puebol Plant. The roasting department has 5 Brückners, 2 O'Harras, besides 10 long-hand reverberatories. There are 7 blast furnaces, taking 150 tons a day with mechanical charging.

The Eilers Plant. Roasting done in 15 reverberatories. Flue dust is briquetted with fine Cripple Creek ore, crude ores rich in silver and 10 per cent. lime. The residues from the U. S. Zinc Co. are smelted direct and run 10 per cent. Pb. There are six blast furnaces.

The Murray Smelter, Utah: O. Pufahl, *E. and M. J.*, 81, 985. Produces monthly 4,000 tons base-bullion and 700 tons lead-copper matte which goes to Omaha and Pueblo respectively. Roasting department consists of 20 Brückners, 12 reverberatories. Eight blast furnaces, 48 × 169 in., with automatic charging.

The Federal Smelting Works, Alton, Ill.: O. Pufahl, *E. and M. J.*, 81, 1034. The ores are smelted in 20 Scotch-hearths, yielding 70 per cent. Pb. The Bag process takes care of the lead fumes which are burnt and sent to the blast-furnace along with the gray slag. The rest of the charge is made up of roasted matte and iron slag. Roasting is done in long hand reverberatories.

The Huntington-Heberlein Process: T. Huntington and F. Heberlein, *E. and M. J.*, 81, 1005. In the early stages the difficulty was to obtain an agglomeration of roasted material and not leady matte. A careful study of the effects of CaO, Fe_2O_8 or Mn_2O_8 lead to the process being a success. The authors discuss the chemical reasons and have moved from a position on dioxide of lime to lime as a contact substance for oxygen.

Experiments on the Metallurgical Behavior of a Mixture of Lead Sulphide and Calcium Sulphate: F. O. Doeltz. *Metallurgie*, II., No. 19; *E. and M. J.*, 81, 175. In his English patent Carmichael states that a mixture of lead sulphide and calcium sulphate react at a dull red heat according to the equation

$$PbS + CaSO_4 = PbSO_4 + CaS.$$

After a series of ten experiments Doeltz concludes that the above reaction does not take place, but on the contrary that when lead sulphate and calcium sulphide are brought together, the tendency is to form lead sulphide and calcium sulphate.

On heating a mixture of galena and gypsum in contact with air, lead sulphate will be formed along with lead oxide, due to the reaction

$$PbO + SO_2 + O = PbSO_4.$$

Theoretical Aspects of Lead-Ore Roasting: C. Guillemain, *E. and M. J.*, 81, 470. Is an abstract from *Metallurgie*, II., 433. Discusses the roasting of galena in general and then goes on to show that in the Hun-

tington-Heberlein process, the theory that calcium dioxide is the active agent is absolutely wrong, for successful work can be done by replacing the lime by manganese and iron oxides.

The Savelsberg Process: E. and M. J., 81, 1136. The difference between this process and the H. and H. lies in the fact that here the raw ore mixed with a suitable proportion of limestone and siliceous flux is blown directly in a converter. Three illustrations show the plant used.

Manganese: Min. Ind., 14, 431. Gives the production of manganese ores in U. S., manganese mining and a table of analyses of the world's manganese ores. In 1905 about 228,000 tons of speigeleisen and 66,000 tons of ferromanganese were produced in the United States.

Molybdenum: Min. Ind., 14, 450. The ores are molybdenite, MoS_2 and wulfenite $PbMoO_4$. The metal can be reduced with carbon in crucibles from molybdic acid. Ferro-molybdenum can be made in the electric furnace or by the use of thermit.

Nickel and Cobalt: E. K. Judd, *Min. Ind.*, 14, 459. Gives the production of nickel and cobalt. Under the heading of progress in the metallurgy of nickel, gives the substance of Morrell's patent which greatly improves the method of separating nickel sulphides by the use of sodium sulphide, and of Maffett's patent which is a new method of treating copper tops in the refining of nickel-copper matte.

Lime Roasting of Nickeliferous Matte: A. C. deJongh, *E. and M. J.*, 81, 793. Describes experiments to show that the presence of lime is beneficial. An artificial matte consisting of NiS, Cu_2S and a small amount of iron was roasted in a muffle down to 1.54 per cent. S. By repeating the work and adding $CaCO_3$ towards end of roast the sulphur was reduced to 0.054 per cent.

On the Converting of Nickel Matte to Nickel by Oxygen: R. Hesse, *Metallurgie*, III., 287. A nickel matte running 73.82 per cent. Ni, 24.13 per cent. S was used. It runs 30 per cent. metallic nickel, 70 per cent. NiS. First of all, the reaction of NiO and NiS was studied, then a small converter was used in which nickel matte was blown. The work shows that the presence of NiS does not prevent Ni from oxidizing.

Tin: W. R. Ingalls, *Min. Ind.*, 14, 534. Deals with the production, mining and markets of tin at home and abroad; gives some notes on the progress of the metallurgy of tin.

The Treatment of Tin Wolfram Copper Ores at the Clitters United Mines: F. Dietzsch, *Trans. I. M. and Met.*, XV., p. 2. The mill consists of 20 stamps, which crush through 25 mesh, and a ball mill crushing through 30 mesh. The combined product passes through 3 Spitzluten over Buss swinging tables, of which there are 8, whilst the fines are run through a clarifying Spitzkasten over 4 double Lührig vanners. The concentrates from the Buss tables contain sulphides of iron, copper and arsenic, oxides of tin and wolfram. They are roasted in Brunton calcine or reverberatory furnace and passed through a Wetherill separator, which give clean tin and clean wolframite, a copper product sold to smelters and tailings. A small sulphuric acid leaching plant has been erected for the copper ore, with precipitation as scrap iron. In addition there is a tungstate of soda plant.

Tungsten: R. Meeks, *Min. Ind.*, 14, 557. Gives the production and price of the ore and metal; tungsten mining; milling; metallurgy. The metal can be prepared by reducing WO_3 in crucibles at a high temperature, or commercially by treating a mixture of ore and coke in a Moissan furnace.

Zinc: W. R. Ingalls, *Min. Ind.*, 14, 562. Deals with the production of ore, zinc, oxide and of spelter.

Progress in the Metallurgy of Zinc: W. R. Ingalls, *Min. Ind.*, 14, 589. Embraces sections on mechanical concentration, roasting furnaces, smelting furnaces.

The Zinc Industry in Silesia in 1905: P. Speier, *E. and M. J.*, 81, p. 176. Tells of the change from the Silesian to the Rhenish type of furnace. The Wetherill and Mechernich systems of magnetic separation are coming more and more into use. For roasting of blende there are now 12 plants in Silesia, in more than half the furnaces of which the gases are used for the manufacture of H_2SO_4.

The Palmerton Works of the New Jersey Zinc Co.: O. Pufahl, *E. and M. J.*, 81, 273. Describes the oxide works, which have 480 kilns, the residues of which are smelted for speigeleisen in the blast furnace. The spelter works consist of two Siemens furnaces with 256 retorts, and two Convers and de Saulles furnaces with 160 retorts each. Furnaces are fired by gas from 12 Dowson producers. The paper mentions the Lithopone works and the sulphuric acid plant, which uses the Grillo-Schroeder process.

The Works of the U. S. Zinc Co. at Pueblo, Colo.: O. Pufahl, *E. and M. J.*, 81, 1233. Smelt blends from dressing silver-lead ores of Colorado. Roasting in 4 Rhenania furnaces of 35 tons and one Hegeler of 40 tons daily capacity. Six Siemens furnaces with 240 retorts each. Gas fired from Duff generators. Residues sent to the Pueblo lead smelters.

The Zinc Industry in the U. S.: H. S. Clark, *Mining Mag.*, XIII., 461. Discusses mode of occurrence, nature and treatment of zinc ores; the use of magnetic machines which follow roasting in certain Joplin ores, but which separate the zinc rich product after drying and crushing to 30 mesh in many of the western ores. The Cleveland-Knowles magnetic separator, the Wetherill and the Blake electrostatic machine are mentioned. Gives some details of smelting and tables of cost of labor on the distillation furnaces at several plants.

The Milan Exposition: P. Nicou, *Bull. Soc. de l'Ind. Minérale*, V., 1905, pp. 1058, 1066. Describes the metallurgical and electro-metallurgical exhibits; products from the Keller and Gin furnaces, etc.

Metallurgy at the Liège Exposition: L. Maillard, *Bull. Soc. de l'Ind. Minérale*, V., 1906, 727. Amongst other exhibits describes those pertaining to the electric smelting of iron and steel. Illustrations showing Gin and Kjellin furnaces are given.

Metallography and Pyrometry.

The Solidification of Copper: P. Dejean, *Rev. de Met.*, III., 233. Authorities give the f. p. of copper from 1035 to 1102° C. The eutectic of copper and copper oxide freezes at 1065° C. using gold 1065° C.

as standard. This eutectic contains 4.5 per cent. Cu_2O. Copper with 0.09 per cent. oxide freezes at 1085° C. The alloys of copper and aluminium show a freezing point curve which falls from the f. p. of Cu to 1039° C. with 8.6 per cent. Al.

The Study of Special Brasses: L. Guillet, *Rev. de Met.*, III., 243. Deals first with ordinary brasses and their constitution, then with brasses containing aluminium, manganese, iron, tin, lead, silicon, magnesium, antimony, phosphorus and cadmium.

Recent Work on Industrial Alloys: L. Guillet, *Rev. de Met.*, III., 155. Takes up the iron-carbon alloys, special steels, ferro-alloys bronzes, brasses and other copper alloys. For the copper phosphorus alloys the curve of fusibility shows a fall from the m. p. of Cu to 612° C., the eutectic alloy into 10 per cent. P., then a rise to 1015° C. with 85 per cent Cu, 15 per cent. P, the compound Cu^3P.

The alloys of copper and silicon show a minimum at 12 per cent. Si, followed by a rise in the freezing point to 35 per cent. Si. The copper. vanadium alloys are solid solutions up to 7 per cent. Va beyond this point, two constituents come in whose composition is not yet determined. Copper does not alloy with chromium or tungsten.

The Use of Metallography in Detecting Spurious Coinage: C. Hoitsema and W. J. van Heteren, *Metallurgie*, III., 128. Shows that there is a difference in structure between the genuine and the spurious.

Lead and Silver: K. Friedrich, *Metallurgie*, III., 396. The freezing-point curve consists of two inclined branches meeting at the eutectic point 2.5 per cent. Ag at 304° C. The alloys have two constituents only Ag and Pb. The second part of the paper is on the Pattinson Process.

Silver and Arsenic: K. Friedrich and A. Leroux, *Metallurgie*, III., 192. A series of alloys were made containing up to 19 per cent. arsenic, their cooling curves and microstructure determined. The eutectic freezes at 527° C. and up to 19 per cent. + As the alloys consist of silver dendrites surrounded by an increasing groundmass or eutectic.

Lead and Arsenic: K. Friedrich, *Metallurgie*, III., 41. A series of alloys running from 0 to 34.4 per cent. As were made. The eutectic contains 2.5–3 per cent. As and freezes at 292° C. The upper freezing point curve shows a uniform rise from this point to 34.4 per cent. As, *i. e.*, above Pb_3As_4 and shows no signs of the supposed compounds Pb_2 As, etc. Nine photographs illustrate the specimens.

The Alloys of Copper and Arsenic: K. Friedrich, *Metallurgie*, II., *Abst. Mining Mag.*, XIII., 145. The alloys between 0 and 21.5 per cent. As consist of dendrites of copper in an increasing eutectic. From the eutectic point 21.5 per cent. to 29 per cent. As we have increasing amounts of the compound Cu_3As set in the eutectic. With increase in arsenic Cu_5As_2 comes in. The curves and microstructure have been worked out up to 45 per cent. As.

Silver and Silver Sulphide: K. Friedrich and A. Leroux, *Metallurgie*, III., 361. The freezing point curve shows a fall from the m. p. of silver 962° C. to 906° C. at 11–15 per cent. Ag_2S from which point the curve is horizontal indicating the formation of two conjugate solutions. A second horizontal line at 806° C. denotes the freezing of the groundmass. A third point occurs at 175° C. due to a change in the solid silver sulphide with the separation of moss-silver.

Copper and Sulphur: Heyn and Bauer, *Metallurgie*, III., 73. The series shows a eutectic with 3.8 per cent. Cu_2S and consists of crystals of copper or of Cu_2S set in this eutectic depending upon whether we have less or more than 3.8 per cent. Cu_2S present. The eutectic freezes at 1067° C. Cu_2S at 1127° C.: but the solubility curve cuts the freezing point curve at 1102° C. and at 9 per cent. and 85 per cent. Cu_2S.

The Iron-Carbon Series of Alloys: F. Wüst, *Metallurgie*, III., p. 1. A series of 20 cast irons were made, whose carbon contents varied from 2.56 to 4.82. Cooling cuvres were made and micrographs taken to illustrate the series and the changes which occur on cooling.

On the Iron-Carbon System: C. Benedicks, *Metallurgie*, III., 393, 425, 466. Discusses the Roberts-Austen, Rooseboom diagram and the reaction at 1000°C.:—

$$\text{Martensite} + \text{graphite} = Fe_3C.$$

Then follows a micrographic study of various alloys from which the author draws conclusions as to the metastable system Iron-Cementite and the stable system Iron-Graphite.

On the Present Position of our Knowledge of the Solidification and Cooling of Iron-Carbon Alloys: P. Goerens, *Metallurgie.*, III., 175. Deals first of all with the series in the molten state. Then takes up the freezing point curve of Roberts-Austen. Osmond and Roozeboom. Photo-micrographs of three white irons containing 3.9 per cent. 4.5 per cent. and 4.8 per cent. C. are given.

On the Alloying of Copper with Iron and Iron-Carbon Alloys: V. O. Pfeiffer, *Metallurgie*, III., 281. For making the copper-iron alloys Swedish iron with 0.037 per cent. carbon was used; whilst for the copper-iron-carbon alloys a Swedish cast-iron with 4.02 per cent. C was used.

Special Steels: L. Guillet, *Metallurgie*, III., 137, 186, 209. Works out the constitution of nickel steels, their mechanical properties and constituents. A chart is given showing constituents in steels with varying per cent. of carbon and of nickel. There are perlitic steels, martensitic steels and those of gamma iron. Next takes up manganese steels and works them out as above.

The Industrial Future of Special Steels: L. Guillet, *I. and S. Magazine*, XI., 89. Deals with Ternary and Quarternary Steels. These can be reduced to five types, (1) pearlitic steels, (2) martensitic steels, (3) gamma iron steels, (4) carbide steels, (5) graphitic steels.

A Defective Bar of Tool Steel: C. E. Corson, *I. and S. Mag.* XI., 281. An article illustrated by eight excellent photo-micrographs showing the variation in structure of a steel with 1.72 per cent. carbon.

ALUMNI AND UNIVERSITY NEWS.

During the coming summer the Departments represented in the Faculty of Applied Science will offer a greater number and variety of courses than heretofore in the Summer Session at the University.

The following is a brief outline of the work thus offered by these Departments:

CHEMISTRY: Courses in general chemistry (both elementary and advanced), qualitative and quantitative analysis, physical, organic and physiological chemistry, and organic and sanitary analysis.

CIVIL ENGINEERING: Courses in hydraulics and in structures, the latter including the design and erection of steel, masonry and concrete structures.

DRAWING: Courses in freehand drawing, in mechanical drawing (both elementary and advanced), and in descriptive geometry.

GEOLOGY: Courses in general geology, geology of North America, and North American index fossils.

MATHEMATICS: Courses in algebra, geometry, trigonometry, analytical geometry, calculus, modern analytical theories in geometry, differential geometry, differential equations, and theory of functions of complex variable.

MECHANICAL ENGINEERING: Courses on gas engines, steam engineering and hydraulics; the first and second courses including lectures and laboratory work, the last laboratory work only.

PHYSICS: Courses in general physics and mechanics, analytical mechanics, methods of teaching physics, and advanced laboratory work.

The Summer Schools conducted by the Applied Science Departments in the field will of course be held as usual.

The greater part of the fourth year class in Mining will go into the field in small squads, as was done last summer. Though all the details were not complete up to the time of going to press, arrangements have already been made for a number of squads at various gold, silver, copper and iron mines in Tennessee, Michigan, Colorado, Montana and British Columbia. Several members of the class will work at mines during nearly the entire summer.

Professor Kemp was the guest of the Canadian Mining Institute at its meeting March 5 to 9 at Toronto, where he read a paper on some "New Points in the Geology of Copper" at one of the sessions, and responded to the toast of the Mineral Industry at the banquet.

Professor Bogert has been elected President of the American Chemical Society.

Early in March, Prof. Henry S. Munroe left for a trip of about three months to one of the mining districts of Bolivia.

With great regret we have to announce the death on March 9 of John Krom Rees, Emeritus Professor of Astronomy. A biographical notice regarding Professor Rees will appear in the next issue of the QUARTERLY. The following minute was prepared for the Faculty of Applied Science by a committee consisting of Professors Van Amringe, Jacoby and Kemp.

John Krom Rees, Professor of Astronomy and Director of the Observatory, who, after a long illness, died March 9, 1907, was graduated Bachelor of Arts from Columbia College in 1872. To a most honorable academic career as a student (he was head of his class) he added the distinction at graduation of becoming, after a severe examination, the first Fellow in Science appointed by Columbia. He subsequently entered the School of Mines and received the degree of Engineer of Mines. Later his Alma Mater conferred upon him the degrees of Master of Arts and Doctor of Philosophy.

He devoted his life to teaching and to scientific work — for several years in Washington University, Missouri, and since 1881 in Columbia. He was an unwearied and successful student and investigator in astronomic science and contributed to its advancement; modest as to his own acquirements and most appreciative of the acquirements and accomplishments of others; in the various offices of honor and trust that he filled, was untiring and cheerful in his labor and conspicuous by the fidelity and quality of his service; sympathetic and sagacious as an instructor and wise in his counsel as an officer; most loyal to his Alma Mater and the interests of the University; and a staunch and faithful friend to those with whom he was associated. The University is the poorer by his death, and his colleagues here record their high appreciation of his character and services and their unaffected sorrow in losing his support and companionship.

BOOK REVIEWS.

Gold Mining Machinery, its Selection, Arrangement and Installation. A Practical Handbook for the Use of Mine Managers and Engineers, including Particulars for the Preparation of Specifications and Estimates. By W. H. TINNEY, Mining Engineer and Manager, Mem. Instn. of Mining and Metallurgy. New York, D. Van Nostrand Co.; London, Crosby Lockwood & Son, 1906, 308 pp., 96 illustrations. Price $5.00.

This manual is divided into eighteen chapters, viz.: Introductory, Motive Power, Engine Erecting, Boilers, Chimneys, Fuel and Feed, Management of Motive Power, Pumping Machinery, Winding Machinery, Air Compressors, Rock Drills, Crushing Machinery, Concentrating and Gold Extracting Plant, Transmission of Power, Transport, Piping and Joints, Construction, Tackle and Tools, and Details for Estimates. There is also an appendix of 22 pages, containing miscellaneous engineering data, such as is usually found in mechanical and civil engineers' pocket-books.

Although, as may be gathered from the title page, Mr. Tinney's experience has been largely in India and other tropical countries, he has refrained from giving prominence to the special features of practice frequently necessary in dealing with the installation of plant under what are likely to be rather abnormal physical conditions. The subject matter, as a rule, is of general application and such as would be expected from an experienced mine manager, well acquainted with the mechanical details of equipment. Much information is given of a nature not often to be found in similar hand-books; in fact, we know of no other book which deals so largely with the minutiæ and actual processes of erecting and operating mining machinery. In Chapter III., for example, the necessary data and suggestions are given for laying out and building an engine foundation, for general power purposes or for hoisting; we have a discussion of the materials, laying out, mason work, aligning, levelling and setting the bed-frame, assembling and adjusting the engine parts, setting the values, etc. Similar descriptive matter is given for boiler installations, including details of erecting chimney stacks; also the precautions to be observed in starting up a new plant.

The chapter on pumping plant is good, though rather brief, considering the numerous types of direct-acting pumps now available in competition with the time-honored Cornish pumping system. In view of the object and scope of the book, we think that, in treating of hoisting plant, more prominence should have been given to the preliminary calculations covering the power and hoisting speed required, as based on daily output and depth of shaft. The working up of such data is essential for submitting outline specifications to the engine builders. The chapters on Air Compressors and Rock Drills are good, though brief; including a quite satisfactory discussion of air consumption per drill and horse-power required.

Under Crushing, Concentrating and Gold-extracting plant, an outline only is given, in some 35 pages. These are very large subjects in themselves and much detail could hardly be expected in a book planned mainly to deal with the plant employed in developing and mining the ore.

Aerial tramways and ropeways are touched on, but together with several other subsidiary subjects, are not treated at length. Chapter XVII., partly on erecting tackle and appliances, is to be commended and will be found valuable in cases where a professional "rigger" is not available.

This is a practical book, written in concise and intelligible style, and we believe it will be appreciated.

R. P.

Lead Smelting and Refining, with some notes on Lead Mining. Edited by WALTER RENTON INGALLS. New York, the Engineering and Mining Journal, 1906. 327 pages, 51 illustrations. Price, $3.00.

This volume contains another of the collections of technical articles previously published in the columns of the Engineering and Mining Journal, which have been appearing in book form during the past few years. The first, entitled, "Sampling and Valuation of Mines," was brought out in 1903 by Mr. T. A. Rickard, then editor of the Journal, and was followed in 1904 and 1905 by "Pyrite Smelting" and "Economic Mining." They were so well received, that Mr. Ingalls, the present editor, continued the series by the publication last year of "Notes on Metallurgical Mill Construction."

The book now before us, the fifth of the series, contains between fifty and sixty articles, grouped under the general heads: "Notes on Lead Mining," "Roast-Reaction Smelting," "Sintering and Briquetting," "Smelting in the Blast Furnace," "Lime-Roasting of Galena," "Other Methods of Smelting," "Dust and Fume Recovery," "Blowers and Blowing Engines," "Lead Refining" and "Smelting Works and Refineries" These headings will indicate the varied nature of the subjects dealt with. A few of the articles come from the Transactions of the American Institute of Mining Engineers, but nearly all, including some abstracts from the proceedings of Engineering Societies or other technical periodicals, are reprinted from the Engineering and Mining Journal. Among the articles of special value are those on the "Desulphurization of Slimes by Heap-Roasting at Broken Hill," by E. J. Horwood; "Cost of Smelting and Refining," by Malvern W. Iles; "The New Method of Desulphurizing Galena," by W. Borchers; also, several papers on the "Huntington-Heberlein Process for Lead Ores," and on "Lime Roasting of Galena." Most of the illustrations are good, though the dimension figures are not always clearly printed.

A book of this kind differs from a treatise or text-book in that the material comes largely from engineers actually engaged in the management of the works or processes of which they write; much of it relates to or embodies the results of the most recent practice and valuable information is given respecting new developments in various lines of metallurgy. It contains in handy form much useful information, which otherwise would have remained scattered and inconvenient for reference.

R. P.

Long Distance Electric Power Transmission; a Treatise on the Hydro-Electric Generation of Energy; its Transformation, Transmission and Distribution. By ROLLIN W. HUTCHINSON, JR. Consulting Electrical Engineer, Assoc. Member Amer. Inst. Elect. Engs. and Member Amer. Electrochemical Society. New York: D. van Nostrand Co., 1907. 345 pp., 136 ills.

The ground covered by this book, which we have just received, is well defined on the title page, transcribed above. There are twelve chapters: Laws of hydraulics; Applied Hydraulics; Hydraulic Machines and Accessory Apparatus; Generators, Switches and Protective Devices; Laws Governing Transmission of Energy; The Transmission Line; Transformers; Motors; Converters; Practical Plants; Distinctive Features of Prominent Long Distance Transmissions.

The first two chapters contain, in 63 pages a clear, brief presentation of so much of the principles of hydraulics and their applications as is essential for the working out of the ordinary problems met by the engineer, and the proper understanding of the machinery usually employed for hydro-electric plants. In dealing with the latter, a sufficient elementary knowledge of mechanical engineering is taken for granted by the author, so that the reader's attention is directed mainly to those details of construction and operation which are necessary for a comprehension of their application to this branch of engineering. The book does not aim to be exhaustive. Hence, historical matter, relating to the development of this class of machinery is omitted. The advances made during the past 10 or 12 years have been so extraordinarily rapid that engineers are sufficiently occupied in keeping abreast of the times.

In the chapters on hydraulic plant much attention is given to water governors as applied to turbines and impulse wheels, the subject matter being illustrated by good cuts. Chapter IV., on generators, switches and protective devices, occupying 50 pages, is excellent throughout; as are also chapters V. and VI., on the laws of electric transmission and the transmission line itself. Under the last-named heads are given the essential facts relating to the erection of pole-lines, together with a detailed example showing the mode of calculation for a 75-mile, 3-phase transmission line.

A discussion of transformers, motors and converters, follows and the work closes with two chapters devoted to brief notes on the design and arrangement of plants, with examples of a few well-known power stations, The book deserves special commendation for the clear and remarkably concise style in which it is written, and its value as a text-book is materially increased by the lists of references following each chapter. R. P.

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CONTENTS:

John Krom Rees. By Harold Jacoby 413
Hydraulic Formulæ: Development and Discussion. By Adolph Black 417
The Calculation of Chemical Equilibria. By K. George Falk 441
Methods of Constructing the Foundations for the Trust Company of America Building. By Maurice Deutsch 459
The Helion Lamp. By W. G. Clark and H. C. Parker 471
Frederick Arthur Goetze, Dean of the Faculty of Applied Science. By G. F. Sever 477
Proposed Testing Laboratory of the Department of Civil Engineering. By Wm. H. Burr 479
Abstracts—Analytical Chemistry. By E. Waller 482
Abstracts of Recent Mining Decisions. By J. W. Thompson 495
Metallurgical Abstracts. By William Campbell 502
Meeting of Columbia Chapter, Society of the Sigma Xi 523
University News 526
Book Reviews 535

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THE

SCHOOL OF MINES

QUARTERLY.

VOL. XXVIII. JULY, 1907. No. 4.

JOHN KROM REES.

BY HAROLD JACOBY.

It is the custom to mark the passing of a well-known man with a short notice of biography; and it is not difficult to recite a list of services, enumerate honors and distinctions conferred by public bodies, or recapitulate scientific researches and publications. But to the writer these things are cold and hard when said of Rees; to him Rees was known best as a friend — that rare friendship of which the beginning is outside the grasp of memory, the end a green sod.

Surely, if there exists a relation adapted better than any other to make one acquainted with the good or bad in any man, it is the relation of a subordinate to his chief. During eighteen long years the writer sat at his work under Rees: in all that time there never came down to him an unkind word; never once did a serious difference of opinion arise. In eighteen years one becomes accustomed to any man; the few like Rees one comes to love. These words will fail signally in their purpose, if they do not convey to his sorrowing family such poor consolation as may come from those who feel and suffer with them.

Rees was but fifty-five on his last birthday; in his short life he had served Washington University as a professor five years, and Columbia University twenty-one. He had been president of the New York Academy of Sciences two years, and secretary of the American Metrological Society fourteen years. For six years he was secretary of the Columbia University Council. He was a fellow of the Royal Astronomical Society of London, a member of the Astronomische Gesellschaft of Leipzig, and in 1901 was cre-

ated a chevalier of the Legion d'Honneur in recognition of his services as one of the judges at the Paris exposition in that year. His principal observational research was a study of the "Variation of Terrestrial Latitudes and the Aberration of Light," made at Columbia University, in coöperation with the Royal Observatory, Naples. This was the first application of the method of simultaneous observations at two stations situated on the same parallel of latitude, but separated widely in longitude. The work was continued from 1893 to 1900: the method has since come into general use; and the International Geodetic Association, which includes all civilized governments, has now established four permanent stations to carry it on.

It was also during Rees's administration that the astronomical department of Columbia University undertook the publication of Rutherfurd's valuable series of star photographs. Through his efforts this enterprise was made possible; he took a keen interest in it, and spared no pains to further the work during a long series of years.

In educational matters Rees was at all times most active. His public lectures were frequent. Characterized especially by lucidity, they always attracted large audiences; people came to hear him again and again. But his most lasting contribution to educational development was his establishment of the Columbia summer school of geodesy. It is probable that he was the first to recognize practical field work in this subject as an indispensable adjunct in the training of civil engineers. Here he was at his best: his point of view always that of the genuine man of science, seeking ever the truth for its own sake; never exalting mere technique at the expense of theoretic perfection; never limiting his exposition of a subject to the side having most value from the financial point of view. Students frequently came back to him in later years; they always spoke of his summer school as the most agreeable memory of their college years. Whenever this occurred, he was a happy man for days.

The following letter from Professor F. R. Hutton shows well the cordial relations that existed between Rees and his professional associates in the days of old Columbia:

"Rees entered the School of Mines in 1872 on graduating from Columbia College. His class was that of Rölker, Weller, Leavens and Wright, who have all risen to high standing in their respective

specialties. Chemistry figured very largely in the old course of study under Bolton, Waller and Kerns, whom all delight to remember whose memory runs back to those old times. The buildings were most inadequate and poorly ventilated, but they hummed with a spirit of busy and ever enthusiastic industry. On graduation Rees went at once to his work at Washington University, St. Louis, where he took a very earnest and vital interest in all matters relating to the university. It was while he lived and labored there that the memorable fire occurred in the Southern hotel, from which Rees and his young wife escaped at peril of their lives and lost all their belongings. They descended from windows on ropes.

"Coming to Columbia as assistant to Professor William Guy Peck, Rees had to begin with very small facilities. A wooden structure on the campus, with a small refracting telescope and a time instrument, were all he had, but he rendered most effective service with this apparatus, not only in descriptive astronomy with college students, but in effective coöperation with the schools of the city, where classes were formed for evening visits to the little observatory, sadly interfering with Rees's dear ambition to do real scientific work. But he felt this an obligation he could not slight. It was a great gain when the new buildings and the library at 49th street were erected, giving at least a mechanical elevation above the horizon of the surrounding roofs; but difficulties from smoke and railroad vibrations, caused by heavier engines and increasing weight and number of trains, all stood in the way of any ambition to rival research observatories. It was a dear dream of his to establish a great observatory on the Hudson at some point remote from the interference of metropolitan conditions.

"On the coming of Professor Trowbridge in 1878 the need of geodetic surveying was at once considered and the courses in geodesy for civil engineers established to meet it. These were also made to furnish necessary preliminary training for the summer school with which Rees was so prominently identified. The first schools were held by him at Cooperstown, N. Y., and continued there until the transfer to Sunapee, N. H., from which place they moved to their present location at Osterville, Mass. The bond between Professors Rees and Peck was a very close and friendly one both during the period of Rees's service as adjunct professor, and later when he was made full professor over the independent department of astronomy."

At times Rees was persuaded to go beyond his quiet field of activity in the university. His most lasting public service to the nation was rendered as secretary of the Metrological Society, in furthering the introduction of standard or railroad time. The late Dr. F. A. P. Barnard, president of Columbia College, made the following reference to Professor Rees in his testament, dated 1886:

"I give to my friend, Professor John Krom Rees, the watch known as my Cosmic Time Watch, as a mark of my regard and of my appreciation of his zealous efforts for the promotion of metrological reform and for the introduction of the now established system of public standard time."

Rees's attitude towards the scientific work of others was one of extraordinary modesty. To him the past masters of astronomy were not men; they were demi-gods, to be mentioned in respectful accents and with lowered tones. Even living visible masters of the craft commanded from him a degree of respect such as he could not have offered even to crowned royalties. His own work might be as good as theirs, but he could never see it so.

Another marked characteristic was his extreme delight when visited by any one to whom it was possible to do a favor. This was his pleasure. No trouble was too great or time-consuming; no return, not even thanks, was expected. No man ever had fewer enemies; his friends equaled in number those who knew him. When at last the heavy weight of disease was laid upon him he met it as a man should. No querulous repining; regret only that his work must stop; his solace that others would carry the good work on. Mother earth, that he loved well to measure and compute, will give him sleep; to him the peaceful end is surely a release.

HYDRAULIC FORMULÆ: DEVELOPMENT AND DISCUSSION.

By ADOLPH BLACK.

It is the purpose of this paper to develop a *General Equation* of discharge; and from it, as special cases, to derive the various formulae for flow through orifices and over weirs of the shapes usually considered. In addition, some general features relating to the investigations which led to the adoption of the practical formulæ (Series 4) will be briefly presented for the purpose of determining their applicability, noting their limitations, and instituting comparisons.

It is to be observed that possible reductions in many of the algebraic expressions which follow have been purposely omitted, in order to preserve the more symmetrical algebraic forms.

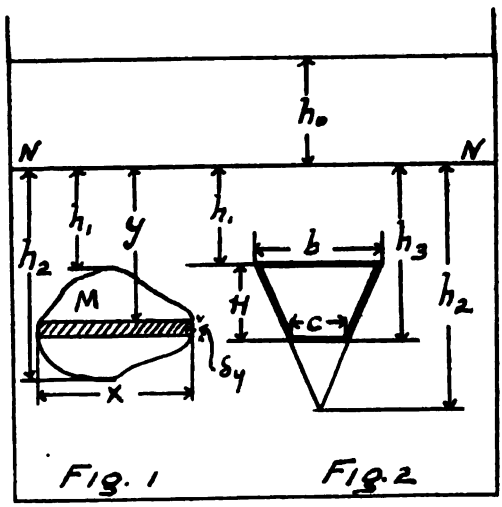


FIG. 1. FIG. 2.

The customary procedure in the development of formulæ expressing the quantity of water discharged through orifices and over weirs of various cross-sections is as follows:

In Fig. 1

Let *M* represent any orifice in the vertical side of a vessel;

h_1 and h_2, the vertical distances of its upper and lower limits below the free water surface $N - N$;

x, the length of an elementary horizontal strip across the orifice at the depth y below $N - N$;

δy, the infinitesimal depth of the strip;

h_0, the velocity head corresponding to the *mean* velocity of approach u; so that $h_0 = u^2/2g$;

H, the vertical dimension of the orifice or weir.

The head may be considered constant throughout the infinitesimal depth δy of the strip; and the effect of the velocity of approach in augmenting the discharge may be considered as due to an increase of the static head over any point by an amount equal to the velocity head. Accordingly, the infinitesimal discharge through the elementary strip is —

$$\delta Q = x\delta y\sqrt{2g(y + h_0)}. \qquad (1)$$

Expressing x in terms of y, as determined by the geometric or trigonometric relations of the particular figure of the orifice under consideration, and integrating the resulting expression between the proper limits to include the entire area of the opening, there results a formula for the discharge for that special case.

In this manner formulæ for the discharge through variously shaped openings have been readily and simply developed, each separately and independently; and it thus happens that the relations of the resulting expressions to each other, and to a common parent form, are not apparent.

Development of the General Formula.

Applying equation (1) to the case of a trapezoidal orifice as exemplified in figure (2), with the notation as indicated, there results

$$\delta Q = \frac{b(h_2 - y)}{h_2 - h_1}\delta y\sqrt{2g(y + h_0)}.$$

The *general integral* of which is —

$$Q = \frac{2}{15}\frac{b\sqrt{2g}}{h_2 - h_1}[5(h_2 + h_0)(y + h_0)^{\frac{3}{2}} - 3(y + h_0)^{\frac{5}{2}}] + C.$$

And the *definite integral* between the limits h_2 and h_1 takes the form —

$$Q = \frac{2}{15}\frac{b\sqrt{2g}}{h_3 - h_1}\left[5(h_2 + h_0)\{(h_3 + h_0)^{\frac{3}{2}} - (h_1 + h_0)^{\frac{3}{2}}\} - 3\{(h_3 + h_0)^{\frac{5}{2}} - (h_1 + h_0)^{\frac{5}{2}}\}\right].$$

Noting that $$h_2 = \frac{bh_3 - ch_1}{b - c},$$

and replacing $h_3 - h_1$ by H, the last equation becomes —

$$Q = \frac{2}{15}\frac{(b-c)\sqrt{2g}}{H}\left[5\left(\frac{bh_3 - ch_1}{b-c} + h_0\right)\{(h_3+h_0)^{\frac{3}{2}} - (h_1+h_0)^{\frac{3}{2}}\} - 3\{(h_3 + h_0)^{\frac{5}{2}} - (h_1 + h_0)^{\frac{5}{2}}\}\right]. \quad (2)$$

This is the **General Equation**, from which formulæ for the various special cases usually considered will now be deduced.

Series 1.

TRAPEZOIDAL ORIFICES AND WEIRS.

Trapezoidal orifice, velocity of approach considered: The formula for this case is given by equation (2).

Trapezoidal orifice, velocity of approach disregarded: In equation (2) make $h_0 = 0$,

$$Q = \frac{2}{15}\frac{(b-c)\sqrt{2g}}{H}\left[5\left(\frac{bh_3 - ch_1}{b-c}\right)\{h_3^{\frac{3}{2}} - h_1^{\frac{3}{2}}\} - 3\{h_3^{\frac{5}{2}} - h_1^{\frac{5}{2}}\}\right]. \quad (3)$$

Trapezoidal weir, velocity of approach considered:

In equation (2) make $h_1 = 0$, and, in accordance with the conventional notation, replace h by H,

$$Q = \frac{2}{15}\frac{(b-c)\sqrt{2g}}{H}\left[5\left(\frac{bH}{b-c} + h_0\right)\{(H + h_0)^{\frac{3}{2}} - h_0^{\frac{3}{2}}\} - 3\{(H + h_0)^{\frac{5}{2}} - h_0^{\frac{5}{2}}\}\right]. \quad (4)$$

Trapezoidal weir, velocity of approach disregarded:

In equation (3) make $h_1 = 0$; or in equation (4) make $h_0 = 0$,

$$Q = \tfrac{2}{15}\sqrt{2g}\cdot H^{\frac{3}{2}}(2b + 3c). \quad (5)$$

A simpler expression may be deduced, in place of equation (4), by adding to the static head H, in equation (5), the term h_0, to introduce the effect of velocity of approach:

Accordingly,

$$Q = \tfrac{2}{15}\sqrt{2g}\cdot(H + h_0)^{\frac{3}{2}}\cdot(2b + 3c). \qquad (4_1)$$

Series 2.

TRIANGULAR ORIFICES AND WEIRS. — In the equations of *Series 1*, make $c = 0$.

Triangular orifice, velocity of approach considered:

$$Q = \frac{2}{15}\frac{b\sqrt{2g}}{H}\left[2(h_3 + h_0)^{\frac{3}{2}} + 3(h_1 + h_0)^{\frac{3}{2}} - 5(h_3 + h_0)(h_1 + h_0)^{\frac{1}{2}}\right]. \qquad (6)$$

Triangular orifice, velocity of approach disregarded:

$$Q = \frac{2}{15}\frac{b\sqrt{2g}}{H}\left[2h_3^{\frac{3}{2}} - 5h_3h_1^{\frac{1}{2}} + 3h_1^{\frac{3}{2}}\right]. \qquad (7)$$

Triangular weir, velocity of approach considered:

$$Q = \frac{2}{15}\frac{b\sqrt{2g}}{H}\left[2\{(H + h_0)^{\frac{3}{2}} - h_0^{\frac{3}{2}}\} - 5Hh_0^{\frac{1}{2}}\right]. \qquad (8)$$

Triangular weir, velocity of approach disregarded:

$$Q = \tfrac{4}{15}b\sqrt{2g}\cdot H^{\frac{3}{2}}. \qquad 9)$$

And the simpler form, which may be used in the place of equation (8):

$$Q = \tfrac{4}{15}b\sqrt{2g}\cdot(H + h_0)^{\frac{3}{2}}. \qquad (8_1)$$

In equations (6) to (8_1) inclusive, *the apex of the triangle is below the base.*

If we suppose *the apex to lie above the base*, the analogies of equations (6) and (7) will be,

$$Q = \frac{2}{15}\frac{b\sqrt{2g}}{H}\left[2(h_1 + h_0)^{\frac{3}{2}} + 3(h_3 + h_0)^{\frac{3}{2}} - 5(h_1 + h_0)(h_3 + h_0)^{\frac{1}{2}}\right], \qquad (6_1)$$

and

$$Q = \frac{2}{15}\frac{b\sqrt{2g}}{H}\left[2h_1^{\frac{3}{2}} - 5h_1h_3^{\frac{1}{2}} + 3h_3^{\frac{3}{2}}\right]. \qquad (7_1)$$

In the majority of cases the sides of the triangle are equally inclined to the vertical; then, if the vertical angle be denoted by 2α,

$$b = 2H \cdot \tan \alpha,$$

and, in equations (6), (7), (8), (6_1) and (7_1),

$$\frac{2}{15} \frac{b\sqrt{2g}}{H} = \frac{4}{15} \tan \alpha \sqrt{2g}; \qquad (a)$$

in equation (8_1)

$$\frac{4}{15} b\sqrt{2g} = \frac{8}{15} H \cdot \tan \alpha \sqrt{2g}, \qquad (b)$$

and equation (9) takes the form —

$$Q = \frac{8}{15} \tan \alpha \sqrt{2g} \cdot H^{\frac{5}{2}}. \qquad (9_1)$$

If the triangle be right-angled at the vertex, tangent $\alpha = 1$, and further reductions may be effected as follows —

(a) becomes

$$\tfrac{4}{15} \sqrt{2g}; \qquad (a_1)$$

(b) becomes

$$\tfrac{8}{15} H \sqrt{2g}; \qquad (b_1)$$

and (9_1) becomes

$$Q = \tfrac{8}{15} \sqrt{2g} \cdot H^{\frac{5}{2}}. \qquad (9_2)$$

Weir with Uniformly Inclined Crest. — The discharge over the weir *EBCD* (Fig. 3) is equal to the difference of the discharges

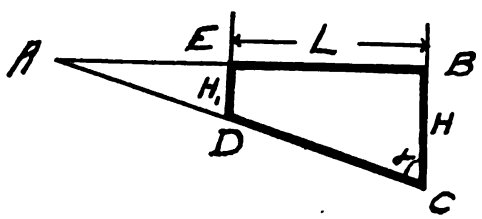


FIG. 3.

over the weirs *ABC* and *AED*. Applying formula (8_1) (b), there results, for this case,

$$Q = \tfrac{4}{15} \sqrt{2g} \cdot \tan \alpha \cdot [H(H + h_0)^{\frac{3}{2}} - H_1(H_1 + h_0)^{\frac{3}{2}}]. \qquad (10)$$

If velocity of approach be disregarded,

$$Q = \tfrac{4}{15} \sqrt{2g} \cdot \tan \alpha (H^{\frac{5}{2}} - H_1^{\frac{5}{2}}); \qquad (11)$$

in which $\tan \alpha = L/(H - H_1)$.

Series 3.

RECTANGULAR ORIFICES AND WEIRS. — In the equations of *Series 1*, make $b = c$.

Rectangular orifice, velocity of approach considered:

$$Q = \tfrac{2}{3} b \sqrt{2g} \cdot [(h_3 + h_0)^{\frac{3}{2}} - (h_1 + h_0)^{\frac{3}{2}}]. \qquad (12)$$

Rectangular orifice, velocity of approach disregarded:

$$Q = \tfrac{2}{3} b \sqrt{2g} (h_3^{\frac{3}{2}} - h_1^{\frac{3}{2}}). \qquad (13)$$

Rectangular weir, velocity of approach considered:

$$Q = \tfrac{2}{3} b \sqrt{2g} \cdot [(H + h_0)^{\frac{3}{2}} - h_0^{\frac{3}{2}}]. \qquad (14)$$

Rectangular weir, velocity of approach disregarded:

$$Q = \tfrac{2}{3} b \sqrt{2g} \cdot H^{\frac{3}{2}}; \qquad (15)$$

and the simplified form, which may be used instead of equation (14):

$$Q = \tfrac{2}{3} b \sqrt{2g} \cdot (H + h_0)^{\frac{3}{2}}. \qquad (14_1)$$

SQUARE ORIFICES AND WEIRS. — Since a square is a rectangle with particular dimensions, it follows that all the equations deduced for the case of rectangles may be used without change when square openings are considered.

APPROXIMATE FORMULÆ.

If h be the static head over the center of an orifice, and if the velocity due to the head $h + h_0$ be considered the *mean velocity* throughout the entire area of the opening, the discharge in the case of a *rectangular orifice, velocity of approach considered*, is

$$Q = bH \sqrt{2g(h + h_0)}. \qquad (12_1)$$

Rectangular orifice, velocity of approach disregarded:

$$Q = bH \sqrt{2gh}. \qquad (13_1)$$

It is demonstrated in most treatises on hydraulics that the discharges computed by the approximate formulæ (12_1) and (13_1) are always too great, in comparison with the results obtained by using the corresponding exact formulæ (12) and (13); further, that the magnitude of the error thus introduced varies in proportion to the ratio of the depth of the orifice to the head over its center. It is

also shown that this error amounts to less than three tenths of one per cent. when the above ratio is less than one half. For such cases, then, the simpler formulæ (12_1) and (13_1) will give sufficiently accurate results.

Coefficient of Discharge.

The formulæ thus far developed are *theoretic*, that is, no account has been taken of the diminution of discharge due to frictional resistances and contraction of the issuing stream of water. This diminution must be taken into account in the foregoing formulæ by the introduction of a factor called the *coefficient of discharge*, usually represented by the letter c; it is a variable, the value of which depends on the kind and size of opening, on the head of water, and on other obscure conditions.

Numerical values for this coefficient have been obtained by direct experiment with various kinds and sizes of orifices and weirs under varying conditions, and the results tabulated for practical use. Its value ranges from about .6 to about .65 for standard orifices and weirs. Accordingly, all the formulæ for *theoretic discharge* which have been deduced may be transformed into corresponding formulæ for *actual discharge* by prefixing to the former the factor c, representing the appropriate coefficient of discharge.

Series 4.

Weir Formulæ of Hamilton Smith, Jr.*

Equations (14_1) and (15) may be considered the bases of this series of formulæ.

Rectangular weir, velocity of approach considered:

$$q = c \cdot \tfrac{2}{3} b \sqrt{2g} \cdot (H + nh_0)^{\frac{3}{2}} \qquad [cf.\ eq.\ (14_1)]. \quad (16)$$

in which $n = 1.4$ for weirs with end contractions, and $1\frac{1}{3}$ for weirs without end contractions.

Rectangular weir, velocity of approach disregarded:

[*in eq.* (*16*) *make* $h_0 = 0$,]

$$q = c \cdot \tfrac{2}{3} b \sqrt{2g} H^{\frac{3}{2}} \qquad [cf.\ eq.\ (15)]. \quad (17)$$

The symbol n represents a coefficient introduced in the attempt to make the analytical relations expressed by the equation conform more closely to the actual conditions of flow. "It seems reasonable to suppose that the additional force produced by the velocity of

* "Hydraulics" (London and New York, 1886).

approach is chiefly that due to the velocity of the section of the feeding stream nearest, or in line with, the section of discharge, where the particles of water fairly begin to form into the escaping vein; this velocity is unquestionably greater than *u*." (*Hamilton Smith, Jr.*) (This topic will be discussed more fully in a subsequent section.)

Weir Formulæ of James B. Francis.*

Equations (14) and (15) may be regarded as the bases of this series of weir formulæ.

It is first to be observed that Francis considered the effect of each end contraction as a virtual reduction of the effective length of the weir by an amount equal to $H'/10$, in which H' represents the *effective head* over the crest, the value of which, from equation (14), is seen to be

$$H' = [(H + h_0)^{\frac{3}{2}} - h_0^{\frac{3}{2}}]^{\frac{2}{3}}. \qquad (c)$$

(This topic will be dealt with fully in its appropriate place.)

Further, taking the mean of the values of the coefficient c, as deduced from his experiments, the factor $c \cdot \frac{2}{3}\sqrt{2g}$ becomes 3.33, a constant, for all cases. Accordingly for a

Weir with n end contractions, velocity of approach considered:

$$q = 3.33\left(b - \frac{nH'}{10}\right)[(H + h_0)^{\frac{3}{2}} - h_0^{\frac{3}{2}}]. \qquad (d)$$

Within the practical limits of applicability of this formula, H and H' differ very little; and accordingly, H may be substituted for H' in the term $\frac{nH'}{10}$, simplifying the formula thus:

$$q = 3.33\left(b - \frac{nH}{10}\right)[(H + h_0)^{\frac{3}{2}} - h_0^{\frac{3}{2}}] \qquad [cf.\ eq.\ (14)]. \qquad (18)$$

Weir with n end contractions, velocity of approach disregarded:

In equation (18) make $h_0 = 0$,

$$q = 3.33\left(b - \frac{nH}{10}\right)H^{\frac{3}{2}} \qquad [cf.\ eq.\ (15)]. \qquad (19)$$

Weir without end contractions, velocity of approach disregarded:

In equation (18) make $n = 0$,

$$q = 3.33b[(H + h_0)^{\frac{3}{2}} - h_0^{\frac{3}{2}}] \quad [cf.\ eq.\ (14)]. \qquad (20)$$

* "Lowell Hydraulic Experiments" (New York, 1883).

Weir without end contractions, velocity of approach disregarded:

In equation (20) make $h_0 = 0$,

$$q = 3.33bH^{\frac{3}{2}} \quad [cf.\ eqs.\ (15)\ and\ (17)]. \qquad (21)$$

WEIR FORMULA OF HUNKING AND HART.*

$$q = 3.33\left(b - \frac{nH}{10}\right)KH^{\frac{3}{2}} \quad [cf.\ eq.\ (18)]. \qquad (22)$$

in which (approximately),

$$K = 1 + \frac{1}{4}\left(\frac{H}{D}\right)^2 = 1 + \left(\frac{H}{2D}\right)^2 \qquad (e)$$

and

$$D = \frac{\text{Sectional Area of Approaching Stream} \equiv S}{b - \frac{nH}{10}}.$$

With a *suppressed* weir, n becomes zero, in which case D is equal to the depth of the approaching stream.

The author states that the limit of applicability of the formula is $H/D = .36$; and that it was devised for the sole purpose of reducing the time consumed and the labor involved in computing by the Francis formula, of which it is merely a modification, or adaptation, as will be clearly seen by the derivation which follows. Within the above limits it agrees with the Francis formula to within $\frac{1}{50}$ of 1 per cent., according to the author.

Equation (22) above will be recognized as the Francis general formula (18), in which $KH^{\frac{3}{2}}$ is substituted for $[(H + h_0)^{\frac{3}{2}} - h_0^{\frac{3}{2}}]$, so that,

$$K = \left(\frac{H + h_0}{H}\right)^{\frac{3}{2}} - \left(\frac{h_0}{H}\right)^{\frac{3}{2}} = \left(1 + \frac{h_0}{H}\right)^{\frac{3}{2}} - \left(\frac{h_0}{H}\right)^{\frac{3}{2}}. \qquad (f)$$

By definition

$$h_0 = \frac{v^2}{2g} = \frac{q^2}{S^2 \cdot 2g} = \frac{3.33^2\left(b - \frac{n}{10}H\right)^2 (H^{\frac{3}{2}})^2 K^2}{S^2 \cdot 2g} = c\left(\frac{1}{D}\right)^2 H^3 K^2,$$

in which $c = 3.33^2/2g$. Dividing both members of the above equation by H—

$$\frac{h_0}{H} = c\left(\frac{H}{D}\right)^2 K^2,$$

* *Journal of the Franklin Institute*, vol. 88, 1884.

which, being substituted in equation (f) gives

$$K = \left[1 + c\left(\frac{H}{D}\right)^2 K^2\right]^{\frac{1}{2}} - \left[c\left(\frac{H}{D}\right)^2 K^2\right]^{\frac{1}{2}}.$$

By solving this equation for K with varying values of the ratio H/D, a curve was constructed from which equation (e) was deduced. It is clearly seen that the effect of velocity of approach is involved in the coefficient K, the value of which may be taken directly from a table in which the argument is the ratio H/D; or, it may be obtained from a suitably arranged diagram, or curve.

Weir Formula of Parmley.*

$$q = C'\left(b - \frac{n}{10}H\right)K'H^{\frac{3}{2}} \quad [cf.\ eqs.\ (18)\ and\ (22)]. \quad (23)$$

This is evidently identical in form with equation (22) of Hunking and Hart. C' is a function of H, and represents the factor $c \cdot \frac{2}{3}\sqrt{2g}$, of preceding formulæ, the coefficient of discharge c here retaining its proper variable character. It therefore corresponds to the constant 3.33 adopted as a mean value by Francis, and by Hunking and Hart; and K' varies with the ratio of the *effective* area of the weir section to the area of section of channel of approach, thus introducing the effect of velocity of approach. In any given case, the values of C' and K' must be taken from a table suitably prepared for this purpose. This formula was developed from a consideration of the experimental results of Francis, Fteley and Stearns, and Bazin; it thus represents, in the numerical values of its coefficients, what may be termed a *compromise* formula; and, in respect to this feature of the development, it resembles the formula proposed by Fteley and Stearns,† which may be briefly summed up as follows:

Formula deduced from experiments upon weir 5 feet long,

$$q = 3.33bH^{\frac{3}{2}} + 0.0065b.$$

Formula deduced from experiments upon weir 19 feet long,

$$q = 3.291bH^{\frac{3}{2}} + 0.004b.$$

* *Trans. Am. Soc. C. E.*, vol. 26, 1900.

† *Trans. Am. Soc. C. E.*, vol. 12, 1883.

Formula deduced from Mr. Francis' experiments,

$$q = 3.313bH^{\frac{3}{2}} + 0.006b.$$

FINAL FORMULA, from an examination of all these results,

$$q = 3.31bH^{\frac{3}{2}} + 0.007b.$$

for a weir unaffected by end contractions, or velocity of approach. If these conditions exist, the corrections for them must be made separately.

Mr. Parmley has shown that his formula, when applied to the experiments of Francis, and of Fteley and Stearns, agrees within about one per cent. through a very wide range of conditions, his results being usually the larger. When applied to the work of Bazin, on the other hand, the results for small heads will be found to be too small by about the same percentage, and for larger heads the difference approaches zero. The formula gives about equal weight to the work of the experimenters mentioned.

WEIR FORMULA OF H. BAZIN.*

Equation (15) may here be considered the basic formula.

$$q = mb\sqrt{2g}\cdot H^{\frac{3}{2}} \tag{24}$$

in which, when *velocity of approach is considered,*

$$m = \left(.405 + \frac{.00984}{H}\right)\left\{1 + .55\left(\frac{H}{H+P}\right)^2\right\}, \tag{g}$$

and when *velocity of approach is disregarded,*

$$m = \left(.405 + \frac{.00984}{H}\right). \tag{h}$$

The effect of velocity of approach is represented in equation (*g*) by the term $.55[H/(H+P)^2]$ in which P is the height of the weir crest above the bottom of the channel of approach; when velocity of approach is disregarded, as when P is relatively large, this term becomes zero, resulting in equation (*h*).

For the development of the above formula, consider equation (16), which, for convenience, may be written in the following form:

* *Annales des Ponts et Chaussées* (Paris, 1898; 2me Trimestre). *Also 1888–1898.*

$$q = \mu l \sqrt{2g}(h + ah_0)^{\frac{3}{2}} = \mu l h \sqrt{2gh}\left(1 + a\frac{u^2}{2gh}\right)^{\frac{3}{2}}*$$

which is expressed in metric measure.

Since the value of $u^2/2gh$ is always quite small, the above equation becomes, by expansion, approximately

$$q = \mu l h \sqrt{2gh}\left(1 + \frac{3}{2}a\frac{u^2}{2gh}\right). \qquad (k)$$

This expression is not convenient for use, since it involves u, the velocity of approach, the value of which depends on the discharge to be determined; therefore noting that

$$\frac{u^2}{2g} = \frac{q^2}{2g \cdot l^2(h+p)^2};$$

replacing q by its value from the simple equation $q = ml\sqrt{2g}\cdot h^{\frac{3}{2}}$; and, for brevity, using K for $\frac{3}{2}am^2$, there results

$$q = \mu\left[1 + K\left(\frac{h}{h+p}\right)^2\right] lh\sqrt{2gh}. \qquad (l)$$

The values of a, K and μ were determined by direct experiment on five weirs of different heights; it was found that a and K were not perfectly constant, but as mean values a was taken equal to $\frac{5}{3}$, and K to .55.

Regarding μ, its value, which corresponds to the limiting case of no velocity of approach, could not be obtained directly, since it is impossible to entirely suppress this velocity; its influence, however, decreases as the height of weir increases. The coefficient μ was found to decrease slowly in value as the head increased; finally, with heads greater than one-tenth meter, it was shown that the value of μ could be represented with sufficient accuracy by the formula

$$\mu = .405 + \frac{.003}{h}.$$

Then, with the proper substitutions as indicated, equation (l) becomes

$$q = \left(.405 + \frac{.003}{h}\right)\left[1 + .55\left(\frac{h}{h+p}\right)^2\right] lh\sqrt{2gh}$$

which, reduced to English measure, becomes equation (24) above.

* *Annales des Ponts et Chaussées* (Paris, 1888, 2me Semestre).

It is important to note that Bazin's formula applies only to the case of *weirs without end contractions*, since the experiments resulting in its establishment were conducted on such weirs.

Weirs with Inclined Faces.

For weirs with faces inclined up or down stream, or both, Bazin's work furnishes a table of moduli, with values depending on the inclinations. The value of m for the corresponding standard, sharp-crested weir is to be multiplied by the proper modulus, to give the coefficient for such a case.

Wide-crested Weirs or Dams.

Bazin's * experiments with weirs of a great variety of forms furnish numerical values for the coefficient m, of equation (24), for heads between about 0.2 and 1.5 feet; and the Cornell University * experiments on large size dams of various cross-sections have made available values of the above coefficients in the case of heads ranging from about 1 to 6 feet. This will be again referred to in a later portion of this paper.

General Considerations.

J. B. Francis.

The earlier hydraulicians in their attempts to allow for velocity of approach assumed that the energy of the entire section of the feeding canal is expended in increasing the discharge over the weir. "It is evident that the force due to velocity of approach, which causes an acceleration of velocity at the weir, must be less than the total kinetic energy of the water as it passes by the measuring point for H. . . . Any attempt to compute the allowance to be made for velocity of approach from the total energy, or *vis-viva* of the water as it passes" this point, "presents many complicated problems. . . ." (*H. Smith, Jr.*)

Francis' method of introducing into his formulæ the effect of velocity of approach is based rigorously on the conception that the force causing increased velocity at the weir is that due to the energy of *a section of the feeding stream having the same area as the area of discharge, and having the mean velocity of the feeding stream.* In effect, he considers his weir to be an orifice of depth H, the upper edge of which is at the depth h_0 below the water

* *Trans. Am. Soc. C. E.*, vol. 26, 1900.

surface, virtually assumed to be measured at such a distance up stream from the weir as to include the additional height h_0, the velocity head of approach. This method differs from that given for similar cases by most of the early writers on hydraulics, "who seem generally to have followed Du Buat ("*Principes d'Hydraulique*," *Paris, 1816*); it agrees, however, with the expression given by Weisbach ("*Allgemeinen Maschinen Encyclopädie*," *Leipzig, 1841*) who appears to have been the first to point out the error." (*J. B. Francis.*) Francis' method of allowing for the effect of end contractions is also unique; on this point he says:

"When a contracted weir is of *considerable length in proportion to the depth of the water flowing over*, the diminution due to the end contractions is evidently a constant quantity, whatever may be the length, provided the depth is the same; we may, therefore, assume that the end contractions effectively diminish the length of such weirs by a quantity depending only upon the depth of water over the weir. It is evident that the amount of this diminution must increase with the depth; we are unable, however, in the present state of (hydraulic) science, to discover the law of its variation; but experiment has proved that it is very nearly in direct proportion to the depth. As it is of great importance in practical applications to have the formulæ as simple as possible, it is assumed in this work that the quantity to be subtracted from the absolute length of a weir having complete contraction, to give its *effective* length, is directly proportional to the depth. It is also assumed that the quantity discharged by weirs of equal lengths varies according to a constant power of the depth. There is no reason to think that either of these assumptions is perfectly correct; it will be seen, however, that they lead to results agreeing very closely with experiment." (*J. B. Francis.*)

The *general form* of Francis' complete formula, equation (*d*) above, is

$$q = C(b - dnh)h^a, \qquad (m)$$

in which h is the effective head H' of equation (*c*). Mr. Francis states that this formula was suggested to him by Mr. Boyden in 1846.

The *construction* of the formula shows very clearly that it cannot be applicable in all cases; for the factor $b - dnh$, representing the *effective* length of the weir, becomes zero if $b = dnh$; again, if

$dnh > b$, the discharge (according to the formula) would be negative; both of which conclusions are absurd.

It seems evident, therefore, that in weirs of very short length, the effect of the end contractions cannot be considered independent of the length, which condition of independence is assumed in the above equation. Clearly the end contractions influence the discharge to a certain distance, A, from each end of the weir; therefore, if the length of the weir be greater than $2A$, we may consider the effect of the end contractions to be independent of the length; but if the length be less than $2A$, the whole breadth of the issuing stream is affected in its flow by the end contractions, and consequently the formula would not apply.

It was found by experiment that when the length of weir was not less than three times the depth of water, the formula would apply very closely; but that for lengths of weir less than this, the formula would not give satisfactory results, the error increasing as the relative length of the weir diminished.

In practice, it is almost always possible to so proportion the weir as to length and depth, that the formula may be used with safety. In suppressed weirs, *i. e.*, weirs without end contractions, the proportion of length to depth is immaterial, in respect to the feature just considered.

Francis' experiments also show that for weirs with end contractions, and with velocity of approach as great as one foot per second, his formula may give results with an error of two-thirds of one per cent. "They indicate that the method of correcting the depth for velocity of approach is not strictly accurate, as might have been anticipated, omitting, as it does, all consideration of the effect produced by this velocity, in modifying the contraction. It is well understood that such an effect is produced, but it is of such a complicated nature, that the investigations hitherto undertaken have thrown but little light upon it." (*J. B. Francis.*) Hamilton Smith's adoption of two values for his factor n, in the term introducing the effect of velocity of approach, corresponding to the cases of weirs with and without contractions, indicates clearly his appreciation of the mutual effect of end conditions and velocity of approach. Fteley and Stearns also recorded observations to the same effect.

Francis measured the heads, h_1 and h_2, when the same quantity of water was passing successively over two weirs of lengths b_1 and b_2; then, applying equation (m), considering C a constant

$$q = C(b_1 - dn_1h_1)h_1^a = C(b_2 - dn_2h_2)h_2^a, \qquad (n)$$

in which d and a were the only terms with unknown values.

"If the formula represents the true law, and the experiments from which the values of the constants are to be derived are perfectly accurate, the particular combination of experiments to be used in the reduction of the equation above is evidently unimportant. As such an assumption would be very unreasonable, we have combined the experiments, with a view of obtaining the best approximation from imperfect data; and this we have accomplished by selecting experiments the most remote from each other in the values of the respective data they furnish." (*J. B. Francis.*)

Successive values of d were assumed, and the corresponding values of a computed, and that value of d was selected which produced the least variation in the computed values of a. This condition was most nearly fulfilled with the value of $d = 0.05$, the corresponding mean value of a being 1.46994, or 1.47 very nearly; consequently, to represent the whole of the experiments with the greatest uniformity, the formula becomes

$$q = C(b - 0.05nh)h^{1.47}. \qquad (o)$$

However, "the values finally adopted in this formula, namely: $a = 3/2$, $d = 0.1$, were decided upon after many trials of other values, in consequence of their giving results according the most nearly with all the experiments, *and at the same time having a convenient degree of simplicity.* It is quite likely that many other values of a and d (probably an unlimited number) might be found that would accord somewhat better with the experiments; a closer approximation than is given by the use of the values adopted could have, however, but little practical value; much less, it was thought, than would be derived from the use of the simpler values assigned." (*J. B. Francis.*)

Thus, finally

$$q = C\left(b - \frac{nh}{10}\right)h^{\frac{3}{2}}, \qquad (p)$$

which is equation (*d*).

It should be observed that the determination of the values of a and d, as just described, is accomplished without a knowledge of the actual value of q, the quantity of water flowing over the weirs. To determine valus for C, however, q must be known.

It is interesting to note that Fteley and Stearns,* concluded from their few experiments bearing on this point, that the effect of end contractions was to virtually decrease the effective length of the weir by an amount depending upon the form of, and depth on the weir, the results varying between .06 and .12 of the head. However, they recommended Francis' rule of .1, because of the more numerous experiments of this nature performed by him. It has already been pointed out that the velocity of approach modifies the end contractions somewhat. It would thus appear, considering the character and results of the experiments upon which Francis based his conclusions, that his formulæ may be used with confidence for rectangular, vertical, sharp crested weirs, with complete contractions, or with contractions completely suppressed, with depths of water over the crest between 6 and 24 inches, for weir lengths not less than three times the depth of water, and with the velocity of approach kept below one foot per second, it being assumed that air has free access to the space below the descending sheet of water. With these conditions observed, the probable error is within 1 per cent.

In discussing the results of the Cornell experiments (*Trans. Am. Soc. C. E.*, vol. 26, 1900), with heads from 1 to 6 feet over the crest, Mr. Horton concluded that Francis' formula was practically verified for heads up to the limit of these experiments, and that its reasonable use for any ordinary head appeared to be justified.

In the tables at the end of his treatise Francis gives computed values for the discharge for heads as high as 3.0 feet, though in the text he advocates the use of his formula only between the limits cited above.

H. Smith, Jr.

The method adopted by Hamilton Smith, Jr., to introduce the effect of velocity of approach, which is essentially that of Fteley and Stearns, and of other earlier investigators, is based on an entirely different conception. Equation (16) may be put into the ollowing form:

$$q = c \cdot 2/3\sqrt{2g}\,.(H + \overline{nh_0})b(H + nh_0).$$

"This mode of expression is faulty, as it assumes that the head representing the effect of velocity of approach *not only adds to the measured head*, thus imparting additional velocity, *but also adds to the section of escape*, or area at the weir. We have used this ex-

* *Trans. Am. Soc. C. E.*, vol. 12, 1883.

pression on account of its simplicity; it gives sufficiently satisfactory results when applied to our experimental data." (*H. Smith, Jr.*) As has been stated before, the symbol n represents a coefficient introduced for the purpose of making the analytical relations expressed by the equation conform more closely to the actual conditions of flow. The symbol h_0 stands for the head of water which would theoretically produce the *mean velocity* in the channel of approach; *i. e.*, an imaginary velocity, which, *if* it existed uniformly throughout the *entire section* of the stream approaching the weir, *would* give the actual stream discharge q. But it is known that the velocity of approach is by no means thus uniform; and that it varies in any vertical approximately as the ordinates of a parabola, whose axis is horizontal and lies, ordinarily, at a distance of about three-tenths the depth of the stream below the water surface. It thus happens that the *average velocity* in the upper portion of the approaching stream, which, on account of its position, is most effective in contributing to the weir discharge, is greater than the *mean* throughout the section, represented by h_0. The introduction of the coefficient n as a factor before h_0 hence appears to be rational.

It must be clearly understood that the correction involved in the term nh_0 is intended to compensate *solely for additional head due to velocity of approach.* With partial or complete side or bottom suppression further allowance must be made, as will appear subsequently. This method, though not strictly accurate, is simple, and gives satisfactory results when the velocity of approach is less than one foot per second; or, in general, when the velocity-head of approach is small in comparison with the effective head over the weir.

"Formulæ, such as that of Boileau ('*Jaugeage des cours d'eau*,' Paris, 1850. '*Traite de la measure des eaux courantes*,' Paris, 1854); those of Weisbach ('*Lehrbuch der Ingenieur*') etc., are intended to apply not only for velocity of approach, but also for suppression, or partial suppression of contraction. When there is complete suppression on the three sides, these causes are very closely related to each other; still we conceive that even then they should be considered not as a whole, but separately. The two phenomena are essentially distinct, and it seems to us that the proper method of investigation to be followed is to attempt, as we have done, to determine" the effect each cause separately in increasing the discharge.

"Hydraulicians have nearly always confounded the effects of suppression and velocity of approach, by considering them together. As we have hitherto shown, there are three causes to be taken into account when the area of the cross-section of the feeding stream at the measuring point for H is not very large in proportion to its virtual area at the weir. They are:

"First.—The head due to velocity of approach, which increases the velocity at the weir.

"Second.—Suppression or partial suppression, which increases this velocity.

"Third.—Losses of head by 'friction' and adhesion, between the measuring point for H and the weir, which diminish this velocity.

"These three causes are entirely distinct, . . ." (*H. Smith, Jr.*)

Smith suggested that an expression in the form of equation (20), with an appropriate coefficient for h_0 greater in value than that of n of his formulæ, "would doubtless be more logical, but would give but little, if indeed any, closer results than" equation (16), "and would involve considerable additional labor in computations." (*H. Smith, Jr.*) Mr. Neville has indeed proposed such a modification, which approximately reduces to

$$q = c \cdot 2/3 b\sqrt{2g}[(H + 2.6h_0)^{\frac{3}{2}} - (2.6h_0)^{\frac{3}{2}}]. \qquad (q)$$

Smith also clearly recognized that the factor n in his formulæ should properly be a variable, the value of which, he believed, should increase with the ratio of the area of cross-section of the feeding canal to that of the weir. "We think it apparent that theoretically our factor n should be a variable, increasing with a_c/a; this view is fairly sustained by the experimental data. . . . The expression $(a_c/a)^{\frac{1}{2}} = n$ would roughly indicate the law of increment in n; n would hence be unity with suppression on three sides, when $a_c = a$, which is probably not far from the truth. Even if there were at hand data from which an expression could be framed which would actually state the rate of increment in n, there would result such a complicated formula for weir discharge as to render it almost fatally objectionable for practical use." (*H. Smith, Jr.*)

Other investigators have proposed different numerical values for the coefficient n; thus, Lesbros made the effective head $H' = H + 1.56h_0$; Fteley and Stearns,* in the reduction of their

* *Trans. Am. Soc. C. E.*, vol. 12, 1883.

experimental data, suggested for weirs without end contractions a variable factor n, with values between 1.33 and 1.87, and the mean value 1.5; and for weirs with end contractions, values ranging from 1.58 to 2.27, with the mean value 2.05. In equation (q) above, n equals 2.6. As already stated, in some cases the value of the factor includes the effect of end conditions of the weir. A critical study of the recorded investigations on this point shows clearly that the proper value to be assigned to the factor n is not a subject for abstract discussion, but depends on the form of the formula in which it is to be used, on the relative position of the point of observation for the head, on the particular method of making the determinations or measurements, on the presence or absence of end contractions, and on the nature and physical conditions involved in the experiments themselves.

The effect of weir end conditions is taken into account in the Smith formulæ by the establishment of two tables of values for the coefficient c, corresponding to the cases of weirs with and without end contractions; and also, as stated above, by adopting different values for the factor n for the two cases, as was noted immediately below equation (16).

The *effective head* in Smith's formula, when velocity of approach is considered, is evidently, from equation (16),

$$H' = H + nh_0,$$

which is essentially different, in form, nature and origin, from the corresponding expression of Francis, equation (c).

Hamilton Smith, after a careful study of all available records, based his conclusions mainly on the work of Francis, and of Fteley and Stearns, as well as on his own experiments.

H. Bazin.

The most elaborate and carefully conducted series of experiments on the flow of water over weirs and dams ever made is that which was carried out by H. Bazin, Inspecteur général des Ponts et Chaussées, between the years 1888–1898, and reported in a succession of masterly studies in the Annales des Ponts et Chaussées for the various years. They are unparalleled in respect to detail and minute research. He estimates that the numerical values of the coefficients for his *standard* weir are correct within one per cent. Bazin conducted his experiments by setting up a standard weir at the head of a long measuring chamber; and, when steady

flow had been established, the head over the weir was carefully measured, and also the volume of water in the measuring chamber. This was repeated a sufficient number of times to give averages, which Bazin considers are accurate within less than one per cent. In this manner values of the coefficients for his standard weir were established for head varying from about 0.16 to about 2.0 feet; after which the experiments on weirs of irregular profiles were made by placing each experimental weir a sufficient distance below the standard weir, and, when the flow had become steady, simultaneously observing the head on each.

Adopting, *provisionally*, for the standard weir, the formula

$$Q = MBH\sqrt{2gH},$$

and similarly, for the weir under investigation,

$$Q = mbh\sqrt{2gh},$$

and equating these two values of Q, since the same quantity of water passes over both weirs in any one experiment, we deduce

$$m = M\left(\frac{B}{b}\right) \times \left(\frac{H}{h}\right)^{\frac{1}{2}}.$$

Bazin's preliminary experiments established values for the coefficient M for the standard weir, for varying values of H; the ratio B/b remained constant for all experiments of any one series; so that in any case the measurement of the heads H and h would at once determine the value of the coefficient m, of the experimental weir, for that particular case. Unfortunately his formula was established from comparative experiments with standard weirs of different length and height within a rather limited range, and with comparatively low heads. Bazin's largest weir was only 6.56 feet long and 3.72 feet high, on which a maximum head of about 1.0 foot was used, on account of restricted volumetric capacity. For heads from 1.00 to 1.32 feet it was necessary for him to reduce the length of this weir one half, or to 3.28 feet; and for heads from 1.32 to 1.77 feet, the latter length was again reduced one half, or to 1.64 feet, while the height was reduced to 3.30 feet. In reference to the experiments made with the last-mentioned weir, Bazin states that as it was possible for the retardation by friction against the side walls to become appreciable

in so small a weir or channel, the observations made therewith were used by him only to deduce the law of increase of the coefficient m for heads greater than 1.32 feet; whereas the more numerous and precise results furnished by the two longer weirs served as the basis for determining the discharge of the standard weir.

It should be noticed that Bazin, Hunking and Hart, and Parmley have placed the correction for velocity of approach in one of the two factorial coefficients which appear in each of their formulæ; whereas Francis, Fteley and Stearns, Smith and others have modified the *observed* head to take account of this velocity, the correction thus appearing in the body of their formulæ.

A comparison of equations (22) of Hunking and Hart, (23) of Parmley, and (24) of Bazin, shows clearly the correspondence of the factors 3.33, C', and $(.405 + .00984/H)$, respectively; and also of the factors involving the effect of velocity of approach, K, K', and $[1 + .55(H/H + P)]$.

In 1899 a series of investigations was commenced at the hydraulic laboratory of Cornell University, which may be considered a continuation and extension of Bazin's work. In general character and main features Bazin's procedure was followed; but with the important difference that in the Cornell experiments *full size* dams of the cross-sectional shapes investigated by Bazin, as well as many other forms, were employed, and under *high heads*. It should also be noticed that no volumetric measurements were made, as in Bazin's investigations, for the purpose of calibrating the standard measuring weir. Owing to a difference in conditions with respect to the entrance of air below the descending sheets of water in these two notable series of experiments, and to the difference in size of dams, in heads of water, and in positions and methods of observation for the heads, it was not to be expected that the values of the coefficients in the two cases would show any great degree of correspondence. The numerical values of the coefficients furnished by the Cornell experiments are probably accurate within six per cent.

In these investigations the large standard weir was 16 feet long, and the maximum head 3 feet, the height of crest being 13.13 feet above the channel bottom; the small subsidiary weir had a length of 6.53 feet, and the maximum head over it was 4.874 feet, the crest height being 5.26 feet.

In comparing Bazin's work with that of Francis, and of Fteley

and Stearns, Mr. Gardner S. Williams (*Trans. Am. Soc. C. E.*, 1900), calls attention to the difference in method and place of measurement of the head in the case of the French and American experimenters, and concludes that for a given head Bazin's formula should give a lower discharge than the American formulæ; but, nevertheless, when Bazin's formula is applied to the work of the American investigators, in which the discharge was measured, it universally gives a higher discharge than was observed; when the American formulæ are applied to the American experiments, they fit excellently; but when they are applied to Bazin's experiments they give a lower discharge than was observed; while Bazin's formula, applied to his own experiments, fits exceedingly well.

In the case of the Francis formula, however, this condition appears to reverse near the upper limit of head investigated by that engineer; for, "the Francis formula gives results below that of Bazin for the lower heads, but the discharge curves for the two cross at a head of about 1.4 feet on a weir 11 feet high, and above that Bazin's gives the lower discharges."

Referring to the *nature* of Bazin's formula, Emil Knichling states that a "rational formula of general applicability should make the value of the coefficient m dependent, not only on "the observed head h, and the height p, of the weir above the bottom of the uniform channel of approach," but "also upon the channel width, or weir length b, thereby allowing the formula for the discharge over a standard weir to pass gradually, with reducing values of the height p, into that for a uniform channel," for example Chezy's formula. He then proceeds to show that this condition is not fulfilled in Bazin's formula.

"The inference is, therefore, justifiable, that Bazin's formula can give correct results only in the neighborhood of the experimental limits from which it was derived, and that discordant results will probably be found if it is applied to conditions considerably beyond said limits." Obviously, also, the original conditions should be reproduced as far as practicable.

In this connection Francis may be quoted: "No correct formula for the discharge of water over weirs, founded upon natural laws, and including the secondary effects of these laws, being known, we must rely entirely upon experiment, taking due care, in the *application* of any formula deduced from them, not to depart too far from the limits of the experiments on which it is founded."

And Hamilton Smith, Jr., in concluding his discussion on the variation of the value of the coefficient of discharge in the case of weirs with varying lengths and heads: "It is hardly worth while to pursue this subject still further into space where we have absolutely lost the guidance of experimental light. Such speculations, though possibly ingenious and plausible, when tested with facts generally prove to be very wide of the truth."

(Contribution from the Havemeyer Laboratories of Columbia University No. 137.)

THE CALCULATION OF CHEMICAL EQUILIBRIA.

By K. GEORGE FALK.

In transformations in which the composition of the substances taking part are changed, the extent to which this change or reaction takes place is dependent upon the amounts of the substances present initially, as well as upon the amounts of the products which are formed in the reaction. Although the effect of the amounts of the substances present had been observed for a comparatively long time, especially by H. Rose, who showed, for example, the decomposition of the alkaline sulphides and of potassium bisulphate by water, the exact formulation of the law underlying these and similar facts is due to Guldberg and Waage, who enunciated the now well-known "law of mass action" in 1867. This law states that the extent of the action in a chemical reaction is proportional to the active masses * of the reacting substances. If, for instance, two substances react to form two different substances, the law states that when equilibrium has been attained, at any temperature all four substances will exist together in certain definite concentrations, and that these concentrations are changed by the temperature but in such a way that for any one temperature the product of the concentrations of the initial substances, divided by the product of the concentrations of the substances formed, is a constant. The general expression of the law is, therefore,

$$K = \frac{C_1 C_2 C_3 \cdots}{C_1' C_2' C_3' \cdots},$$

in which $C_1, C_2, C_3, \cdots$ denote the concentrations of the reacting substances, $C_1', C_2', C_3', \cdots$ the concentrations of the substances formed, and K the constant of the law of mass action.

In 1884 van't Hoff deduced the following relation † between K, the heat of reaction Q, and the absolute temperature T, at which the reaction takes place:

* Amount of each present in the unit of volume.

† The derivation of this relation is given in the footnote on p. 447.

$$Q = RT^2 \frac{d \log_e K}{dT},$$

R denoting the molecular gas constant (see page 443).

This equation holds for reversible isothermal reactions, and shows how the constant may vary with the temperature, but it does not permit the determination of K or the equilibrium at any temperature without making use of results obtained from this same equation for a different temperature.

In 1906 Nernst * showed that by making a very simple assumption regarding the heat of a reaction and the external work done by the reaction, this expression could be integrated, and the integration constant determined by appropriate physical measurements. The equations obtained by this deduction permit of the calculation of the equilibrium of a chemical reaction from its heat of reaction and the heat capacities of the reacting substances. Whether the original assumption is true or not can only be determined by comparing the calculated results with those determined experimentally, and it may be stated in advance that the agreement between the results obtained in these ways is very satisfactory.

In the following pages the steps which lead up to the problem will be traced after which the methods used by Nernst to arrive at a solution will be given, as well as a few numerical calculations to show how the final equations are applied to concrete examples. In order not to complicate the calculations unnecessarily, the deductions will be applied to reactions taking place in homogeneous gaseous systems only.

In every transformation, whether physical or chemical, the law of the conservation of energy states that the total amount of energy of the system remains constant. If the decrease in the total energy of the system is denoted by Q, the external work done by the system by A, and the amount of heat absorbed during the transformation by U, then

$$Q = A - U. \tag{1}$$

Applied to a chemical reaction Q is the change in the total energy of the reacting substances, $-U$ the heat of reaction † at

* *Göttinger Nachrichten*, 1906, Heft 1. The complete work has since been published. "Experimental and Theoretical Applications of Thermodynamics to Chemistry" by W. Nernst.

† Other forms of energy will not be considered in the deductions as they all can be calculated in terms of heat units.

constant pressure and A the work done in overcoming the external pressure. If no external work is done, that is, if the reaction takes place at constant volume, $A = 0$ and therefore $Q = -U$, or the heat of reaction at constant volume is equal to the change in the total energy of the system.

In transferring a quantity of heat U from the absolute temperature T to the temperature $T + dT$, a certain amount of work will be required. If the process is carried out in a reversible manner, the second law of thermodynamics gives as the relation between the external work dA required, and the quantity of heat transferred, U, the expression *

$$dA = U\frac{dT}{T}. \tag{2}$$

Eliminating U from equations (1) and (2)

$$A - Q = T\frac{dA}{dT}, \tag{3}$$

Q denoting the decrease in the total energy of a reversible process carried out isothermally at the absolute temperature T and measured by the heat of reaction at constant volume in the case of a chemical reaction, and A the maximum external work which can be obtained and which is equal to RT in the equation $pV = RT$ for every additional gram molecule of gas formed by the reaction (R being the molecular gas constant = 1.985 gram calories). $A - Q$ is the amount of heat withdrawn from the surroundings to keep the temperature of the system constant, and has been called the "latent heat of the reaction." This latent heat of reaction is equal to the product of the absolute temperature and the temperature coefficient of the maximum work. Helmholtz called A the change in the free energy of the reaction and $A - Q$ the change in the bound energy.

A special case of equation (3) is the Clausius-Clapeyron formula, deduced by Clausius and verified experimentally by Clapeyron, showing the relation between the molecular latent heat of vaporization, λ, of a liquid, its vapor pressure, p, and the molecular volumes, V and V', of the vapor and liquid respectively. The ex-

* This expression is deduced in almost all text-books of physics or physical chemistry and therefore its derivation will not be given here. It may be remarked, however, that dA and U must be expressed in the same units of energy.

ternal work done in evaporating one gram molecule of a liquid is equal to

$$A = p(V - V').$$

Differentiating with respect to T,

$$\frac{dA}{dT} = \frac{dp}{dT}(V - V').$$

The change in the total energy of the system is equal to the heat of reaction at constant volume, or in this case, the negative value of the heat of vaporization (since this heat is absorbed), plus the external work done (since heat energy is lost in doing this work), that is,

$$Q = p(V - V') - \lambda,$$

from which by substituting in equation (3) is obtained

$$\lambda = T\frac{dp}{dT}(V - V'), \tag{4}$$

the equation of Clausius-Clapeyron.

If small vapor pressures only be considered, V' will be negligible in comparison to V, and, letting C denote the concentration of the vapor, since $V = 1/C$ and $p = CRT$, equation (4) becomes

$$\lambda = \frac{T}{C} \cdot \frac{dCRT}{dT}$$

and finally *

$$\lambda - RT = RT^2 \frac{d \log_e C}{dT}. \tag{5}$$

In this expression $\lambda - RT$ denotes the change in the total energy of the process (increase if vaporization is considered, decrease if condensation), and may therefore be put equal to Q.

The heat of vaporization of a substance is changed only slightly with the temperature. This variation may be expressed by the series

$$\lambda - RT = Q = \lambda_0 + aT + bT^2 + cT^3 + \cdots, \tag{6}$$

λ_0 representing the heat of vaporization at temperatures close to

* $dCRT = RTdC + RCdT$, R being constant.

$$\lambda = \frac{T}{CdT}(RTdC + RCdT) = \frac{RT^2}{dT} \cdot \frac{dC}{C} + RT = RT^2 \frac{d \log_e C}{dT} + RT.$$

the absolute zero, $a, b, c, \cdots$, depending upon the specific heat of the substance as will be shown later. Combining equations (5) and (6),

$$d \log_e C = \frac{dT}{RT^2}(\lambda_0 + aT + bT^2 + cT^3 + \cdots),$$

which on integration gives

$$(7) \quad \log_e C = -\frac{\lambda_0}{RT} + \frac{a}{R}\log_e T + \frac{b}{R}T + \frac{c}{2R}T^2 + \cdots + i,$$

i denoting the constant of integration.

The heat evolved in a reaction varies according to the temperature at which the reaction is allowed to take place. This change may be shown as follows: *

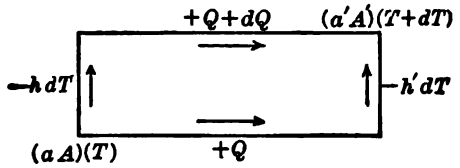


FIG. 1.

From the initial state (a, A) and absolute temperature (T), the same final state and temperature $(a', A')(T + dT)$ is reached by allowing the substances in the one case to react and then raising the temperature of the products to $T + dT$, and in the other case by raising the temperature of the initial substances to $T + dT$ and allowing them to react at this temperature. If h and h' denote the heat capacities of the substances before and after the reaction, and Q and $Q + dQ$ the heats of reaction at T and $T + dT$, then, since the change in total energy must be the same

$$Q - h'dT = -hdT + Q + dQ,$$

or

$$\frac{dQ}{dT} = h - h'.$$

The change in the heat of reaction per degree of temperature is therefore equal to the difference in the heat capacities of the reacting substances before and after the reaction. This is evidently true for the heat of vaporization as well as for chemical reactions. Since the specific heats of substances vary continuously and only

* This diagram (Fig. 1) is taken from Nernst, *l. c.*, page 11.

slightly with the temperature, the following series may be taken to represent this variation:

$$H_v = \alpha + 2\beta T + \cdots$$
$$h_0 = \alpha_0 + 2\beta_0 T + \cdots,$$

H_v denoting the heat capacity of a gram molecule of a vapor at constant volume, h_0 that of the liquid phase, and $\alpha, \beta, \cdots \alpha_0, \beta_0, \cdots$ quantities which may be determined experimentally for any substance by determining its specific heat over a wide range of temperature.

Differentiating equation (6) with respect to T, and introducing the change in the heat of vaporization per degree by means of the specific heats,

$$(8) \quad \frac{d\lambda}{dT} = a + R + 2bT + \cdots = H_v - h_0 + R$$
$$= \alpha - \alpha_0 + 2(\beta - \beta_0)T + \cdots + R,$$

and consequently, since the coefficients of the like powers of T must be equal to each other $a = \alpha - \alpha_0$, $b = \beta - \beta_0$, etc. Substituting these values in equation (7)

$$(9) \quad \log_e C = -\frac{\lambda_0}{RT} + \frac{a - \alpha_0}{R}\log_e T + \frac{\beta - \beta_0}{R}T + \cdots + i,$$

in which all the quantities with the exception of the integration constant i permit of experimental determination, and the evaluation of i is therefore made possible.

In exactly the same way a chemical reaction may be considered. If the heat evolved is denoted by Q, the variation in the amount of heat evolved with the temperature may be expressed by the series:

$$(10) \quad Q = Q_0 + aT + bT^2 + cT^3 + \cdots,$$

Q_0 denoting the heat of reaction in the neighborhood of absolute zero, and by differentiating

$$(11) \quad \frac{dQ}{dT} = \Sigma\nu H_v + \Sigma n h_0 = a + 2bT + 3cT^2 + \cdots,$$

in which $\Sigma\nu H_v$ and $\Sigma n h_0$ denote the algebraic sums of the heat capacities of all the substances taking part in the reaction, $\Sigma\nu H_v$ for those in the gaseous state, and $\Sigma n h_0$ for those in the solid or

liquid state. As before, the change in the specific heat with the temperature may be expressed by the series:

$$\Sigma\nu H_v = \Sigma\nu\alpha + 2T\Sigma\nu\beta + \cdots,$$
$$\Sigma n h_0 = \Sigma n a_0 + 2T\Sigma n\beta_0 + \cdots, \tag{12}$$

which, when substituted in equation (11) gives

$$\frac{dQ}{dT} = \Sigma\nu\alpha + \Sigma n a_0 + 2T(\Sigma\nu\beta + \Sigma n\beta_0) + \cdots, \tag{13}$$

and consequently, from equations (11) and (13),

$$a = \Sigma\nu\alpha + \Sigma n a_0, \quad b = \Sigma\nu\beta + \Sigma n\beta_0, \text{ etc.}$$

Taking up now the relation between equilibrium of a chemical reaction, denoted by the equilibrium constant K, the heat, Q, evolved by the reaction, and the absolute temperature T at which the reaction is allowed to take place, van't Hoff deduced, as already stated, the relation *

$$Q = RT^2 \frac{d \log_e K}{dT}. \tag{14}$$

* This relation will be deduced briefly here. A reversible gaseous reaction is allowed to take place isothermally at the temperature T in a closed vessel in which after equilibrium has been attained the partial pressures of the initial and formed substances are denoted by $p_1, p_2, \cdots p_1', p_2', \cdots$. Let the substances be introduced into the closed vessel through a semi-permeable membrane, and the products formed removed in the same way. If the pressures without the vessel of the initial and formed substances be denoted by $P_1, P_2, \cdots P_1', P_2', \cdots$, the work done in introducing one gram molecule of each substance into the vessel will be equal to $RT \log_e p_1/P_1$

$$\left(\text{since work equals } Vdp = RT\frac{dp}{p} = \int_{P_1}^{p_1}\frac{dp}{p} = RT\log_e\frac{p_1}{P_1}\right),$$

and in removing one gram molecule $RT \log_e P_1'/p_1'$. Two gram molecules of the same substance may be considered separately, as exponents are then avoided in the calculation. In the first case work is lost, in the second gained, therefore the total external work gained will be

$$A = RT\log_e\frac{P_1'P_2'\cdots}{p_1'p_2'\cdots} - RT\log_e\frac{p_1p_2\cdots}{P_1P_2\cdots},$$

or

$$A = RT\log_e\frac{P_1'P_2'\cdots}{P_1P_2\cdots} - RT\log_e\frac{p_1p_2\cdots}{p_1'p_2'\cdots}.$$

Since the substances within the vessel are at equilibrium $p_1p_2\cdots/p_1'p_2'\cdots$ must be constant. This is equal to K, the constant of the law of mass action (see page 442), and the expression becomes

$$A = RT\log_e\frac{P_1'P_2'\cdots}{P_1P_2\cdots} - RT\log_e K.$$

Combining this equation with equation (10) in which the values for $a, b, \cdots$ have been substituted

$$Q_0 + (\Sigma\nu a + \Sigma n a_0)T + (\Sigma\nu\beta + \Sigma n\beta_0)T^2 + \cdots = RT^2 \frac{d \log_e K}{dT}.$$

Integrating,

$$(16) \quad \log_e K = -\frac{Q_0}{RT} + \frac{\Sigma\nu a + \Sigma n a_0}{R} \log_e T + \frac{\Sigma\nu\beta + \Sigma n\beta_0}{R} T + \cdots + I,$$

or, if reactions in the gaseous state only are considered, denoting by Q_0' the heat evolved at a temperature close to the absolute zero,

$$(17) \quad \log_e K' = -\frac{Q_0'}{RT} + \frac{\Sigma\nu a}{R} \log_e T + \frac{\Sigma\nu\beta}{R} T + \cdots + I,$$

K' denoting the equilibrium constant with all the substances in the gaseous state, and I the undetermined constant of integration.

This holds true for a reaction proceeding at a constant temperature. To obtain the expression for the variation of the constant K with the temperature, it will be necessary to introduce the concentrations of the substances instead of their partial pressures into the equation, since at constant volume, the concentration of a substance does not change with the temperature, although its vapor pressure does. The equation becomes, therefore,

$$(15) \quad A = RT \log_e \frac{C_1' C_2' \cdots}{C_1 C_2 \cdots} - RT \log_e K.$$

If the relation between the concentrations of the substances at equilibrium only is desired, the external work becomes in this case

$$A' = RT \log_e K' \qquad \left(K' = \frac{1}{K}\right).$$

Differentiating this equation

$$dA' = R \log_e K' dT + RT d \log_e K',$$

but since $dA' = Q dT / T$,

$$Q = RT \log_e K' + \frac{RT^2 d \log_e K'}{dT},$$

or

$$Q - A' = \frac{RT^2 d \log_e K'}{dT},$$

A' represents the work done when the whole amount of heat Q is involved in the change and is that part of this heat which is transformed into work, therefore $Q - A' = Q'$ represents the heat given off as heat of reaction, or

$$Q' = RT^2 \frac{d \log_e K'}{dT},$$

or in its general form without the primes, as given in the text.

It is impossible to advance any further toward a solution of the problem concerning the relation between the equilibrium constant of a chemical reaction and the heat evolved by the reaction without making some new assumption. The integration constant I cannot be evaluated as the problem stands, and without knowing its value a true solution of this equation is not possible.

In order to attempt the solution of this equation or of equation (14) from which it is derived, Nernst took up the question of the relation between the external work done by a reaction and the change in total energy (heat evolved at constant volume) as formulated in equation (3). According to this equation, at the absolute zero ($T = 0$), $A = Q$, that is, the heat evolved is equal to the external work done. At higher temperatures this is in general not true. Nernst assumes that both A and Q vary continuously with the temperature, but in such a manner that, for reactions in which only solid and liquid substances take part, for a few degrees above absolute zero they are still practically equal, and only then begin to differ sensibly from each other. The curves representing A and Q would have the forms represented by II and not by I, as

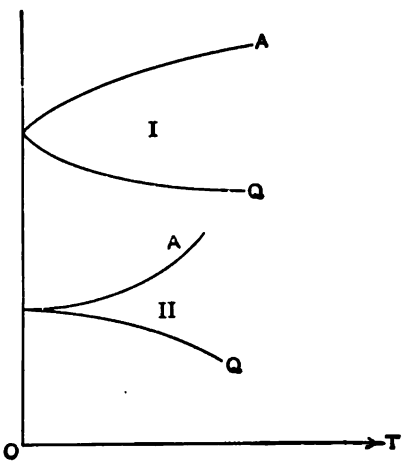


FIG. 2.

shown in Fig. 2, being tangent to each other in the neighborhood of the absolute zero before diverging. Since A and Q are assumed to be continuous functions of T, they may be represented by the series,

$$Q = Q_0 + aT + bT^2 + cT^3 + \cdots, \tag{10}$$

in which $a, b, \cdots$ may be calculated from the specific heats of the reacting substances as shown before, and

$$A = A_0 + a'T + b'T^2 + c'T^3 + \cdots, \tag{18}$$

A_0 and Q_0 being the corresponding values at and near the absolute zero and therefore equal to each other. Substituting these series for A and Q in equation (3),

$$A_0 - Q_0 + (a' - a)T + (b' - b)T^2 + (c' - c)T^3 + \cdots = a'T + 2b'T^2 + 3c'T^3 + \cdots,$$

therefore,

$$A_0 = Q_0, \quad a' - a = a', \quad b' - b = 2b', \quad c' - c = 3c', \quad \text{etc.},$$

and

$$A_0 = Q_0, \quad a = 0, \quad b = -b', \quad c = -2c', \quad \text{etc.} \tag{19}$$

Since $a = 0$ * and according to the assumption made lim. $dQ/dT = dA/dT$ when $T = 0$, in order for the curves representing A and Q to converge as they approach absolute zero and become tangent to each other, a' must also equal zero. The new assumption may therefore be formulated very concisely, namely,

$$a' = 0.$$

It was shown in the deduction of the van't Hoff equation † that the maximum work of a reaction may be obtained by means of the expression

$$A = RT \log_e \frac{C_1' C_2' \cdots}{C_1 C_2 \cdots} - RT \log_e K, \tag{15}$$

$C_1', C_2', \cdots C_1, C_2, \cdots$ denoting the concentrations of the saturated vapors of the different substances taking part in the reaction, and K, as usual, the equilibrium constant. Since equation (9) holds for all substances, the right side of this equation may be substituted for the concentrations of the different vapors in (15), each substance retaining its own characteristic coefficients and value of i. For $\log_e K$ the value obtained from equation (17) may be substituted.

* This expression ($a = 0$) brings to light some interesting relations regarding the specific heats of compounds at very low temperatures, but it will be impossible to go into this part of the subject here. Cf. Nernst, *l. c.*, p. 48.

† See footnote, p. 448.

The heat of reaction (only solids and liquids taking part) near absolute zero is, however, equal to the heat of reaction in the gaseous state minus the heat of vaporization, that is,

$$Q_0 = Q_0' - \Sigma\nu\lambda_0.$$

Equation (15) becomes, then,

$$A_0 + a'T + b'T^2 + c'T^3 + \cdots = Q_0 + (\Sigma\nu i - I)RT - \Sigma\nu a_0 T \cdot \log_e T - \Sigma\nu\beta_0 \cdot T^2 - \cdots.$$

Since this equation holds for all temperatures, the corresponding coefficients of the different powers of T must be equal to each other and consequently

$$(\Sigma\nu i - I)R = a'$$

or, since $a' = 0$,

$$\Sigma\nu i = I. \tag{20}$$

The undetermined integration constant I of equation (17) is thus shown to be resolved into a number of integration constants i, each of which is peculiar to one of the substances taking part in the reaction and depending upon certain definite physical properties of that substance, as shown, for example, by equation (9).

In order to calculate the integration constant for any substance, it would apparently suffice to substitute in equation (9) experimental data for the quantities $\lambda_0, a, \beta, \cdots$ and solve for the unknown constant i. Transforming this equation by means of the expression $p = CRT$, it becomes

$$\log_e p = -\frac{\lambda_0}{RT} + \frac{R + a - a_0}{R}\log_e T + \frac{\beta - \beta_0}{R}T + i + \log_e R \tag{21}$$

higher powers of T being disregarded. Unfortunately, sufficient experimental data to calculate i from this equation are not at hand, and this apparently simple method cannot be used. Going back, however, to the equation of Clausius-Clapeyron from which this is derived, it is possible by suitable substitutions based upon experimental facts to obtain an expression similar to equation (21) for which data are at hand, which will permit of the evaluation of the integration constant.

Nernst found the following empirical formulas to hold over a rather extended range of temperature and pressure:

$$p(V - V') = RT\left(1 - \frac{p}{\pi}\right)$$

(V and V^1 denoting the molecular volumes of vapor and liquid respectively, p the vapor pressure at the absolute temperature, T, and π the critical pressure of the substance); and

$$\lambda = (\lambda_0 + 3.5T - \varepsilon T^2)\left(1 - \frac{p}{\pi}\right)^*$$

(all the symbols having the same significance as before, ε being a constant for a given substance to be calculated as shown in the footnote).

Substituting in the equation of Clausius-Clapeyron

$$\lambda = T\frac{dp}{dT}(V - V'),$$

$$(\lambda_0 + 3.5T - \varepsilon T^2)\left(1 - \frac{p}{\pi}\right) = T\frac{dp}{dT}\cdot\frac{RT}{p}\left(1 - \frac{p}{\pi}\right),$$

or

$$RT^2\frac{d\log_e p}{dT} = \lambda_0 + 3.5T - \varepsilon T^2.$$

Integrating, this becomes

$$(22) \qquad \log_e p = -\frac{\lambda_0}{RT} + \frac{3.5}{R}\log_e T - \frac{\varepsilon}{R}T + i + \log_e R.$$

---

* ε may be calculated as follows: Considering small vapor pressure where p/π is small compared to 1, this equation reduces to

$$(a) \qquad \lambda = \lambda_0 + 3.5T - \varepsilon T^2 - \lambda_0\frac{p}{\pi},$$

which on differentiation becomes

$$\frac{d\lambda}{dT} = 3.5 - 2\varepsilon T - \frac{\lambda_0}{\pi}\cdot\frac{dp}{dT}.$$

For all practical purposes since $\frac{dp}{dT} = \frac{\lambda p}{RT^2}$

$$\frac{\lambda_0}{\pi}\cdot\frac{dp}{dT} = \frac{\lambda\lambda_0}{RT^2}\cdot\frac{p}{\pi}$$

and therefore

$$\frac{d\lambda}{dT} = 3.5 - 2\varepsilon T - \frac{\lambda\lambda_0}{RT^2}\cdot\frac{p}{\pi}.$$

or, for the vapor pressure p_1 corresponding to the temperature T_1

$$(b) \qquad \varepsilon = \frac{1}{2T_1}\left(3.5 - \frac{d\lambda}{dT} + \frac{\lambda_1\lambda_0}{RT^2}\cdot\frac{p_1}{\pi}\right).$$

λ_0 is not known directly, but since the effect of the last term is small, an approximate value for ε is calculated, which, substituted in equation (a) gives an approximate value for λ_0 with which the more exact value of ε is obtained from (b) and then the true value for λ_0 from (a).

Combining the quantities in this equation which are constant, and introducing Briggsian for natural logarithms, the following expression is obtained, C denoting a constant characteristic for every individual substance and which may be calculated for any substance for which the necessary physical measurements have been made.

$$(23)\quad C = \frac{i + \log_e R}{2.3023} = -\frac{\lambda_0}{4.571 T_1} - 1.75 \log T_1 + \frac{\varepsilon}{4.571} T_1 + \log p_1.$$

These constants, C, have been called by Nernst "chemical constants." They are used in calculating the integration constant I of equation (17) which is simply the algebraic sum of the chemical constants of the substances taking part in the reaction. The following is a partial list of the constants which have thus far been calculated.*

H_2	2.2	Cl_2	3.0	H_2S	3.0	NH_3	3.3
CH_4	2.5	I_2	4.0	SO_2	3.3	H_2O	3.7
N_2	2.6	HCl	3.0	CO_2	3.2	$CHCl_3$	3.2
O_2	2.8	N_2O	3.3	CS_2	3.1	C_6H_6	3.1
CO	3.6						

In order to test the correctness of the assumption

$$a' = 0$$

it will be necessary to apply the equation deduced, to the calculation of the equilibria of chemical reactions at different temperatures for which accurate experimental data are at hand with which the calculated values may be compared. For this purpose the following reactions have been chosen from those given by Nernst.

$$\text{I.}\quad 2H_2 + O_2 = 2H_2O,$$
$$\text{II.}\quad 2CO + O_2 = 2CO_2,$$
$$\text{III.}\quad 2SO_2 + O_2 = 2SO_3.$$

The equations used in these calculations will be given in a form which permits of their being applied directly to any gaseous reaction for which the required measurements have been made.

Introducing $\Sigma \nu i$ for I in equation (17) it becomes

* Nernst deduced an expression for the chemical constants containing quantities which may be determined somewhat more easily than those given in equation (23), but as the new expression is similar to (23) it will not be given here.

$$(24)\quad \log_e K' = -\frac{Q_0'}{RT} + \frac{\Sigma\nu\alpha}{R}\log_e T + \frac{\Sigma\nu\beta}{R}T + \cdots + \Sigma\nu i.$$

As the equilibria are to be studied in the gaseous state in which it is more convenient to measure the partial pressures of the constituents than their concentrations, since

$$K' = \frac{p_1 p_2 \cdots}{p_1' p_2' \cdots} \quad \text{and} \quad C = \frac{p}{RT},$$

$$(25)\quad \log_e K' = -\frac{Q_0'}{RT} + \frac{\Sigma\nu(\alpha + R)}{R}\log_e T + \frac{\Sigma\nu\beta}{R}T + \Sigma\nu(i + \log_e R).$$

From equation (12)

$$\Sigma\nu(\alpha + R) = \Sigma\nu H_p^0 = \Sigma\nu(H_v^0 + R) = \Sigma\nu(1.5 + 2) = \Sigma\nu 3.5.*$$

Introducing Briggsian logarithms and substituting

$$C = \frac{i + \log_e R}{2.3023},$$

equation (25) becomes

$$(26)\quad \log K' = -\frac{Q_0'}{4.571T} + \Sigma\nu 1.75 \log T + \frac{\Sigma\nu\beta}{4.571}T + \Sigma\nu C.$$

$\Sigma\nu\beta$ may be calculated as follows (H_p^0 and H_v^0, denoting the heat capacities at absolute zero):

$$H_v = H_p - R = \alpha + 2\beta T, \quad H_v^0 = \alpha,$$

$$H_p^0 = \alpha + R, \quad \text{or} \quad \alpha = H_p^0 - R,$$

therefore $H_p = H_p^0 + 2\beta T = 3.5 + 2\beta T$, and consequently

$$(27)\qquad \Sigma\nu\beta = \frac{\Sigma\nu H_p - \Sigma\nu 3.5}{2T},$$

in which $\Sigma\nu H_p$ denotes the algebraic sum of the molecular heats at constant pressure of the reacting substances at the absolute temperature T.

Q_0' may be calculated from the relation (cf. equation (10))†

* The limiting value toward which the atomic heats of all substances tend as they are cooled down to the absolute zero appears to be 1.5, whereas the molecular heats of gases at constant pressure near absolute zero is equal to $3.5 + 1.5\,n$ (n denoting the number of atoms in each molecule), from which the relation is obtained that near absolute zero the molecular heat of the vapor exceeds that of the solid phase by 3.5 calories.

† Since $Q = Q_0 + aT + bT^2$, for gaseous systems the relation

$$Q_p' = Q_0' + \Sigma\nu(\alpha + R)\,T + \Sigma\nu\beta\,T^2$$

must hold.

$$(28) \qquad Q_p' = Q_0' + \Sigma\nu 3.5T + \Sigma\nu\beta T^2,$$

Q_p' denoting the heat of reaction at constant pressure at the temperature T, while for $\Sigma\nu\beta$ the value obtained from equation (26) is substituted. The expressions $\Sigma\nu 1.75$ in equation (25), and $\Sigma\nu 3.5$ in equations (26), (27), and (28), are to be taken as many times as there is a decrease of one in the number of molecules in the reaction which is being studied.*

In this way all the quantities needed for the application of equation (26) may be obtained. By means of equations (26), (27), and (28), the equilibrium of a chemical reaction for any temperature may be calculated if Q_p', the heat of reaction, $\Sigma\nu H_p$, the molecular heats of the reacting substances at a definite temperature, and the chemical constants $\Sigma\nu C$ of these substances are known,

I. $$2H_2 + O_2 = 2H_2O.$$

$H_p = 8.02$ for H_2O and 6.9 for H_2 and O_2 at $T = 450$. Therefore

$$\Sigma\nu\beta = \frac{3 \times 6.9 - 2 \times 8.02 - 3.5}{2 \times 450} = 0.0012,$$

$$Q_p' = 116000 \text{ when } T = 373,$$

therefore

$$Q_0' = 116000 - 3.5 \times 373 - 0.0012 \times (373)^2 = 114600.$$

Substituting in equation (26)

$$\log K' = -\frac{25050}{T} + 1.75 \log T + 0.00028T - 0.2$$

since

$$\Sigma\nu C = 4.4 + 2.8 - 7.4 = -0.2.$$

In order to permit of a direct comparison with the results obtained experimentally, the calculations may be made with regard to the percentages formed. Since

$$K' = \frac{[H_2]^2[O_2]}{[H_2O]^2},$$

denoting by x the degree of dissociation by volume of the water (very small in this case),

* This is evident from the fact of the final equation having been derived from equation (15) in which the number of terms in the numerator of the fraction denotes the number of gram molecules at the outset of the reaction, and the number of terms in the denominator, the number of gram molecules formed from these.

$$K' = \frac{[x]^2\left[\frac{x}{2}\right]}{[1-x]^2},$$

or since x is very small compared to 1,

$$K' = \frac{x^3}{2},$$

which, introduced into the equation gives *

$$3 \log x = -\frac{25050}{T} + 1.75 \log T + 0.000287 + 0.1.$$

Since the experimental results give the equilibrium (or percentage dissociation) for a given temperature, in order to make the results more easily comparable, the temperature corresponding to the dissociation found has been calculated. Using the values found experimentally by Nernst and Wartenberg,† since the percentage dissociation will be $100x$, the following results are obtained:

$100x$	T(obs.)	T(ca'c.)
0.0189	1480	1455
0.199	1800	1745

The calculated results are in very good agreement with the experimental. It is of some interest to calculate the percentage dissociation for the ordinary temperature ($T = 290$). This is found to be equal to $10^{-25.31}$ per cent., that is, there is practically complete union of the hydrogen and oxygen at the ordinary temperature. This is apparently contradictory to the fact that hydrogen and oxygen may be kept in contact with each other for years without apparent union, but when it is remembered that the laws of thermodynamics do not concern themselves with the velocity of a reaction, but only give the state of the system at equilibrium, this difficulty disappears. Hydrogen and oxygen react so slowly at ordinary temperatures that no change can be perceived, but if a catalyst such as platinum black is introduced, since a catalyst does not change the equilibrium of a reaction but only its velocity, union takes place at once until practically all the hydrogen and oxygen have united.‡

* Since $\log K' = \log x^3/2 = 3 \log x - 0.3$.

† Ztschr. f. phys. Chem., **56**, 534.

‡ Hydrogen peroxide, if formed as the primary product, would not change the equilibrium which only depends on the products actually present at equilibrium.

II. $$2CO + O_2 = 2CO_2.$$

H_p for CO_2 is equal to 10.05, for CO and O_2 to 6.9 at $T = 473$.

$$\Sigma\nu\beta = \frac{0.6 - 3.5}{946} = -0.0030.$$

$$Q_p' = 136000 \quad \text{when} \quad T = 290,$$

therefore

$$Q_0' = 136000 - 3.5 \times 290 + 0.0030 \times (292)^2 = 135300,$$

$$\log K' = -\frac{29600}{T} + 1.75 \log T - 0.00066T + 3.6,$$

$$\Sigma\nu C = 7.2 + 2.8 - 6.4 = 3.6.$$

Letting x denote the degree of dissociation as before, $K' = x^3/2$ and

$$3 \log x = -\frac{29600}{T} + 1.75 \log T - 0.00066T + 3.9.$$

Since $100x$ is the percentage dissociation, the following table is obtained:

$100x$	T (obs.)	T (calc.)
0.00419	1300	1369
0.029	1478	1552

The agreement between the observed and calculated values is not as good as in the first example, but is still satisfactory. The dissociation of carbon dioxide at the ordinary temperature is calculated to be $10^{-29.35}$ per cent.

III. $$2SO_2 + O_2 = 2SO_3.$$

H_p for SO_2 is equal to 9.8, for O_2, 6.9, and for SO_3 it may be placed equal to 11.0, all at $T = 430$.

$$\Sigma\nu\beta = \frac{4.5 - 3.5}{860} = 0.0011.$$

$$Q_p' = 45200 \quad \text{when} \quad T = 290,$$

therefore

$$Q_0' = 45200 - 3.5 \times 290 - 0.0011 \times (290)^2 = 44100.$$

$$\log K' = -\frac{9600}{T} + 1.75 \log T + 0.00024T + 3.2,$$

$$\Sigma\nu C = 6.6 + 2.8 - 6.2 = 3.2.$$

Comparing the results with some of those determined experimentally by Bodenstein, the following table is obtained:

$$\left(K' = \frac{[SO_2]^2[O_2]}{[SO_3]^2}\right)$$

K'	T (obs.)	T (calc.)
0.0010	801	834
0.033	900	949
1.09	1062	1098
7.81	1170	1202

These examples may serve to show the method of applying the equation deduced by the aid of the new assumption to reactions for which the necessary physical constants are known. The extension to reactions in which solids or liquids as well as gases take part, and the calculation of electromotive forces by the use of this equation are comparatively simple, and since no new principles are involved, will not be gone into here. The determination of the stability of chemical compounds follows directly, since it is identical with the question of the extent to which a compound is formed under given conditions.

In the above pages an attempt has been made to show the development of the theory of Nernst, by which the equilibrium of a chemical reaction can be calculated if the heat evolved by the reaction, the specific heats of the reacting substances, and the chemical constants of these substances are known. These quantities can all be measured very accurately, and therefore the extent to which a chemical reaction takes place can be determined by the use of certain physical constants of the substances involved in the reaction.

LABORATORY OF PHYSICAL CHEMISTRY.

METHOD OF CONSTRUCTING THE FOUNDATIONS FOR THE TRUST COMPANY OF AMERICA BUILDING, NEW YORK CITY.

By MAURICE DEUTSCH, C. E.

A typical example of tall building foundation work in lower Manhattan Island is furnished by the foundations recently completed for the Trust Company of America's new twenty five story building, at 41 Wall Street. The new tall building in this section of Manhattan universally replaces a building of less height and usually is adjacent to comparatively low structures whose foundations seldom go down to rock and often do not reach to the basement levels of the new skyscraper. The result is that the problems of providing for exceedingly heavy column loads and of working in a confined space are complicated by the necessity of taking care of the neighboring buildings by underpinning. In the foundation work being described all these typical features are displayed to the fullest extent.

General Description.

A general view of the new Trust Company of America Building is given in Fig. 1, Fig. 2 showing the foundation plan. The building is of the standard steel cage construction, with its steel frame work extending 330 feet above the curb level and two stories below curb level. There are 27 main columns carried on concrete piers sunk by the pneumatic caisson process to bed rock 80 feet below curb level. As the subcellars and boiler rooms are about 30 feet below water level it was necessary to construct a solid, impervious retaining wall continuously around the perimeter of the plot and reaching down to a solid stratum, and it will be noted from Fig. 2 that the wall caissons are continuous on three sides. The south side of the lot is adjacent to the Wall Street Exchange Building, with its cellar enclosed by a similar caisson wall. Connections were, therefore, made between these caissons and those in the Trust Company's Building so as to complete the ring without sinking a separate line of caissons for the fourth side.

FIG. 1. Trust Company of America Building.

Referring to the caissons themselves, it was necessary on the southwest corner of the lot to build a special 14- by 31-foot caisson. This caisson supports five columns. The other wall caissons have dimensions ranging from 5 by 14 feet to 6 by 26 feet. The caissons in the interior of the lot are 7, 8 and 9 feet square. All the caissons are built entirely of wood. The 14 by 31-foot caisson had

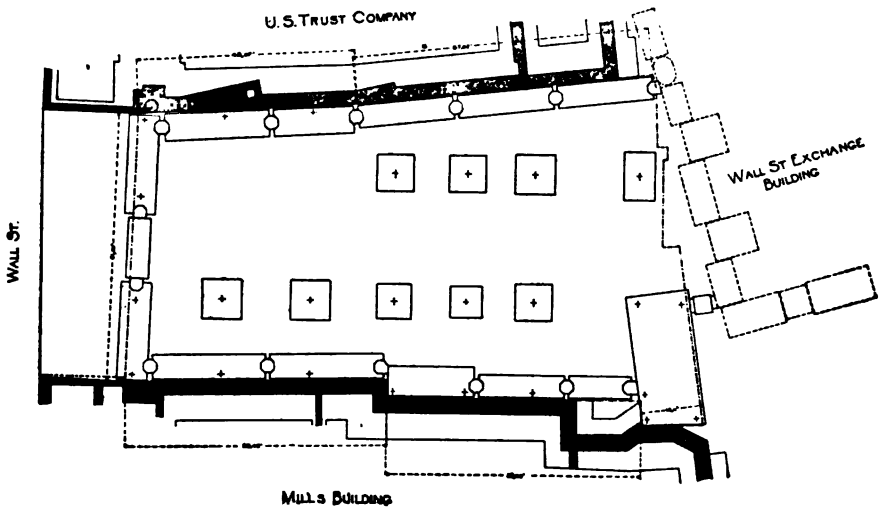


FIG. 2. Plan of Foundation.

an estimated weight of 20 tons. This made it too large and heavy to be brought to the site in a single piece, and it was, therefore, built, assembled, and match-marked at the Greenpoint Yard of the contractors, and then taken apart and the parts shipped to the site, where they were reassembled in 12 hours. The other caissons were trucked to the site and set in position by the traveller booms. The largest of the caissons weighed 12 tons.

THE AIR LOCK.

To permit the passing in and out of a bucket or of the men from the outside air of the caisson, or *vice versa*, without excessive loss of compressed air, air-locks were employed, as is customary in work of this character. The particular type of lock used here was invented by Mr. Daniel E. Moran (Class '84, C.E.), vice-president of the Foundation Company. This air lock surmounts the top of the shaft leading to the working chamber, and it is now

possible to sink caissons through quicksand and water close to adjoining buildings without causing a flow of material from under the latter, which if allowed to occur, would cause them to settle and crack. This is the kind of apparatus which has made possible the construction of the skyscrapers in lower Manhattan. The method of operation of this air lock is clearly indicated in Fig. 8.

Underpinning Work.

The first task undertaken was the work of underpinning the two adjacent buildings — the Mills and the U. S. Trust Co. buildings. More correctly, this work, and the work of wrecking the old building were begun and carried on simultaneously. Briefly described, the underpinning work consisted in building concrete filled steel cylinders under the old building walls and extended them down to bed rock. The location of these cylinders are indicated by the circles on the plan, Fig. 2

On the basement floor level of the old building niches 5 by 5 feet were cut through the cellar walls and into but not through the side walls of the adjacent buildings. The character of these niches is indicated in Fig. 3; they were spaced about 9 feet apart. The cutting of these niches proved to be a considerable task. The work had to be done between 5 P. M. and 9 A. M., so as not to disturb the tenants during business hours, and the cement laid brick masonry proved to be exceedingly hard. The method of cutting out the masonry was to drill holes at close intervals, about 400 for each niche, and then break out the brick work between the holes by means of wedges and hammers. For drilling through the first wall, two Crippen Mfg. Co.'s electric drills, one 2 h. p. and one 4 h. p., were used, and then for the deeper holes in the second wall Ingersoll-Sergeant steam drills with 1¼-inch bits were used. The drilling was very tedious, it requiring about 12 hours to drill with one machine five 2-inch by 4 foot holes through the first wall.

The niches were cut alternately and, as each was finished, riveted steel pipe 36 inches in diameter was placed in it and jacked down to bed rock against the weight of the building. A 60-ton jack was used and the mode of operation was as follows: The first section of pipe 4 feet long with a reinforced cutting edge was put in place and excavation and jacking down begun. As soon as there was room enough a second 4-foot pipe was connected to the first and the excavation and jacking down were continued. In this way one

pipe after another was placed until the cylinder reached bed rock. In connecting up the pipes a steel plate diaphragm with a downward opening door was inserted at the joint between the first and second, and also at the joint between the second and third. These

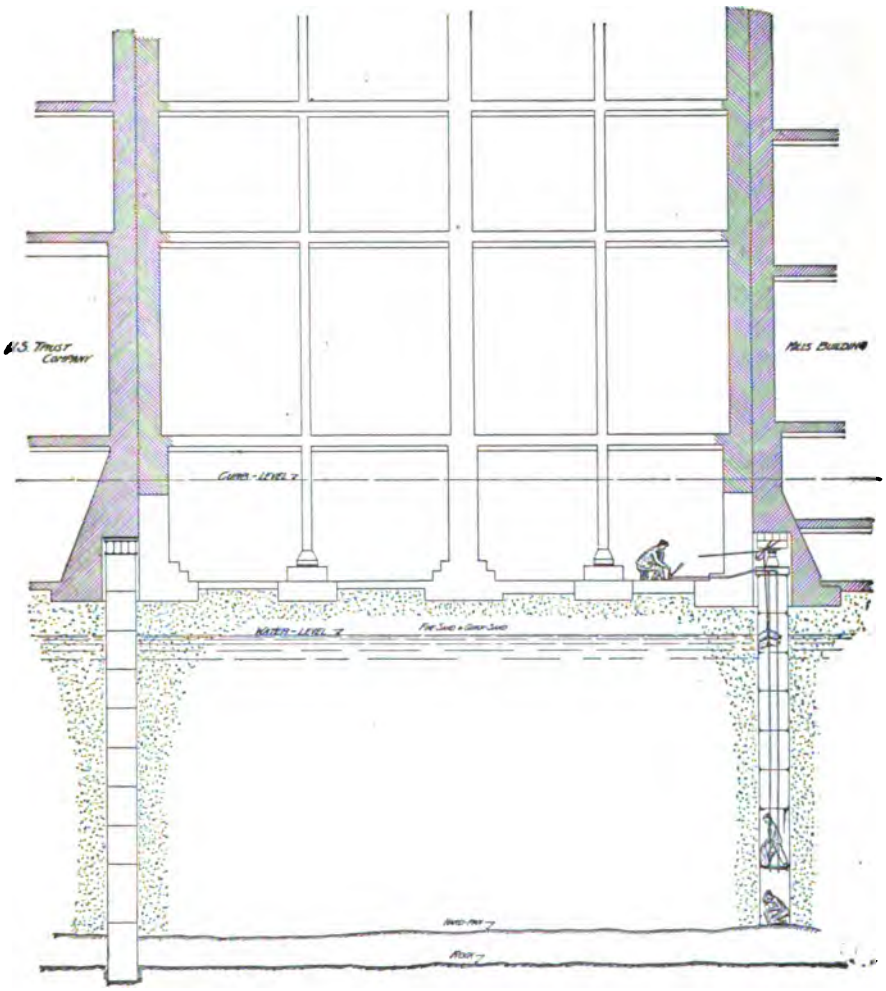


FIG. 3. Section showing method of shoring adjoining buildings before the wrecking of the old building.

diaphragms formed an air-lock, with a working chamber below, by means of which compressed air was put on when the cylinder got below the water line (Fig. 3).

There were about 13 feet of hard pan overlying the rock; above this were sand and earth. The softer materials were taken out with scoops and the hard pan by means of a sort of mattock, made by cutting off one arm of a pick and shortening the helve. The spoil was loaded into bags and hoisted to the top of the cylinder. One man worked in the working chamber and a second in the air-lock, and two other men aided in the hoisting and handling of muck and materials. Three eight-hour shifts were worked and one cylinder was sunk and filled with concrete in seven days. The air pressure used in this cylinder sinking averaged 18 pounds per square inch and reached a maximum of 24 pounds. The concrete filling was a 1–2–4 mixture. Altogether 23 cylinders were sunk without injury to a single man, and no serious trouble, though some slight distortion of the cylinders was observed. The cylinders were capped with I-beam grillages, on top of which the brickwork was filled in.

The work of underpinning was completed before the wrecking had been finished. The contractors then drove four rows of piles to hard pan and constructed on them a working platform at about curb level. On this platform a four-boom traveler was mounted. The arrangement is shown clearly by Fig. 4. The traveler was all steel, with a tower 29 by 29 feet square and 30 feet high, having a 50-foot boom at each corner. It weighed 20 tons, ran on a 24-foot gage track, and was equipped with boilers and four double-drum Lidgerwood hoisting engines. The weight given above was exclusive of the machinery. This traveler was used to wreck the old building below the curb level and for handling all materials used in the foundation work and all the muck excavated. It is so designed that it can be easily dismantled and reërected on new work.

Caisson Work.

The dimensions of the several caissons have been given in a preceding paragraph. All the caissons were four-sided boxes with sides of solid timbers drift-bolted together. The large 14- by 31-foot caisson had interior bracing, but the others were clear inside and of the simplest box form. The mode of procedure was as follows:

The caisson was set by the traveler and accurately located. The material inside was then taken out by open excavation until the caisson had sunk to ground water level at a depth of about 4 feet below

the old footing level. Then the open top of the caisson was roofed over. First a roof of two-inch plank was constructed, supported at the edges by the caisson walls and inside by temporary vertical shores set endwise on the ground. A section of cofferdam was

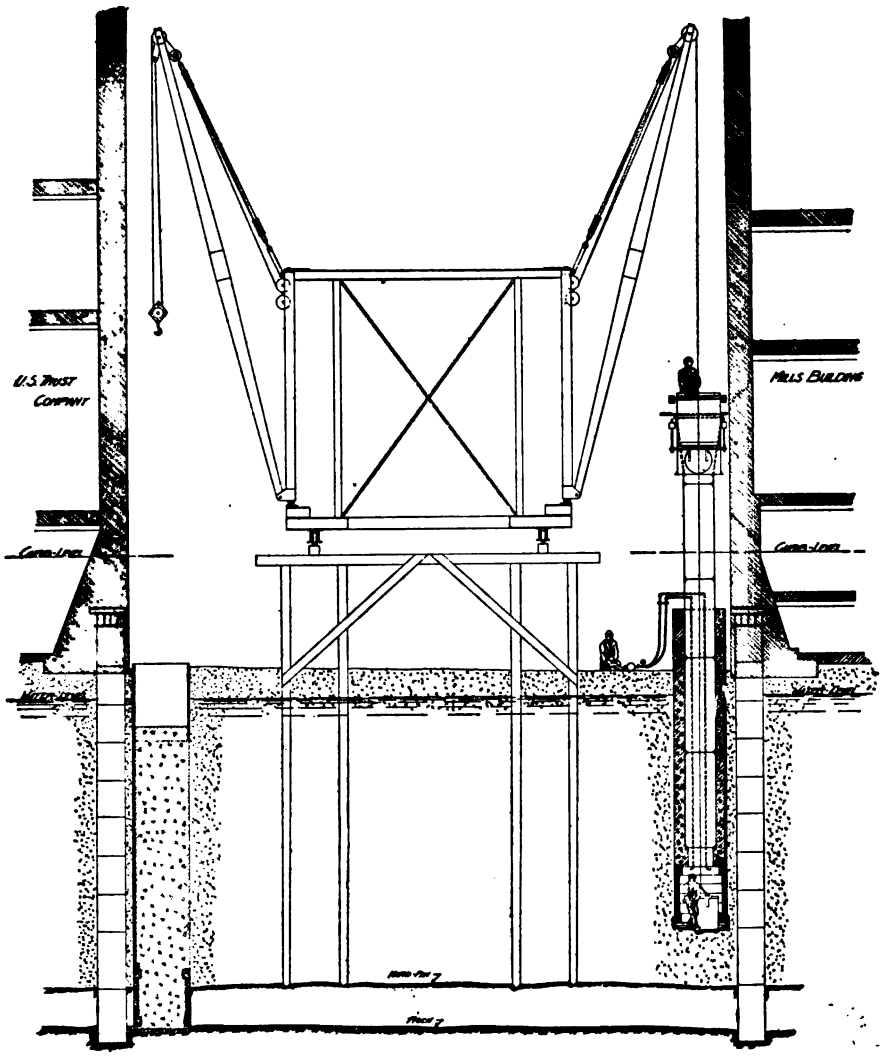


FIG. 4. Section showing method of sinking caissons.

then erected which continued the sides of the box upward 10 feet. On the plank roof, which was only temporary, there was placed first a 6-inch layer of 1–2 mortar and then an 18-inch layer 1–2–4

concrete. After the concrete had set about 12 hours it formed a slab of sufficient strength to carry the wet concrete with which the cofferdam was filled in successive thin layers so as not to distort the sheeting. This method of filling was accomplished by putting a layer of concrete in one form and then shifting the work to the next; one gang thus concreted several caissons, going from one to another and then back to the first. This procedure allowed the layer in each form several hours to harden before another layer was deposited. Just before the first section of cofferdam was completely filled a second section was erected on its top. After concreting had advanced somewhat in this second section, the first section was stripped from the concrete, to be in turn erected on top when the time for this came. In this manner, with two sections of cofferdam, the concrete pier was built up to nearly its full height before the caisson was sunk any further than has already been described. A 1–2½–5 concrete was used for filling above the roof slab.

The working shaft was at the middle of the caisson; it was constructed by forming the concrete around a metal tube of oval section reaching to above the pier top and surmounted by an air lock. The only novelty of this construction was the construction of the metal tube so that it could be removed from the concrete and used again for another caisson. The tube was 30 inches wide and 51 inches long, and was made of ¼-inch steel plate in sections 10 feet long having inside circumferential flanges. The shell of each section was divided by vertical inside flanged joints into three parts, one of which was quite narrow. In placing the concrete the outside of the shaft was oiled and then a strip of oiled paper was in addition placed over the narrow shell piece before mentioned. When therefore the caissons had been sunk and conditions were in shape for concreting the air shaft the steel tube was removed by unbolting the joints of each section, pulling the narrow keypiece in and collapsing the remainder of the shell. The tube was thus saved for another caisson, a practice which was new to this work.

The caissons were sunk in the usual manner by excavation with pick and shovel. The material penetrated to the hard-pan was 45 feet of quicksand, in passing through which the cutting edge of the caisson was kept about 12 inches below the bottom of the excavation and a pressure of 20 pounds of air was maintained. To facilitate the

sinking the caissons were weighted with two ton cast iron blocks, and it is to be noted that the number of these required was greatly reduced by the plan adopted of building the concrete pier to nearly its full height before sinking below the preliminary "set" of the caisson was begun. In a word nearly the full weight of the pier was had for sinking purposes. Work on the caisson was carried on in three 8-hour shifts per day and the maximum speed of sinking was about 25 feet in 24 hours. The sketch, Fig. 4, indicates the process of sinking quite clearly.

As soon as each caisson had been bottomed in the hard pan the working chamber was concreted under pressure. The air shaft tube was then removed as previously described and the whole concreted in the open. About 3,000 cubic yards of concrete was required for all the caissons and underpinning cylinders combined.

Bonding and Wall Piers.

By referring back to Fig. 2 it will be noted that the wall piers were all bonded together to form a continuous wall to keep the water from the basement and sub-basement rooms. The method of performing this task was briefly as follows:

The wall caissons were sunk with a clear space of 12 inches between their ends. Midway of the end faces the concrete had been formed around semi-octagonical timber cores, so as to have a vertical groove from bottom to top of each piece on each end face. The arrangement is indicated by the rough sketch, Fig. 5. As soon as two adjacent caissons had been sunk, the 12-inch space between the two cores was excavated, the workmen as fast as the excavation cleared the boards *A* removing them, and, after sawing to length, nailing them in the positions *BB*, thus forming an octagonical well. It should be stated that for the first four feet at the top the cores were 42 inches wide and 27 inches deep, but below this point the depth of the core was reduced 3 inches or to 24 inches while the width remained the same. Now, as soon as the

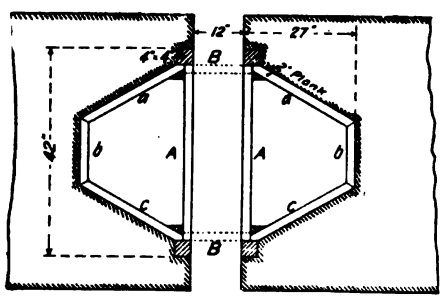


FIG. 5. Sketch showing method of joining 2 concrete caissons.

well before described had been completed to the depth of 4 feet, the core planks *aa*, *bb*, and *cc* were removed, leaving the concrete burr. A 2-foot length of 30-inch steel cylinder was set in the well concentric with the opening, and the annular space between it and the walls

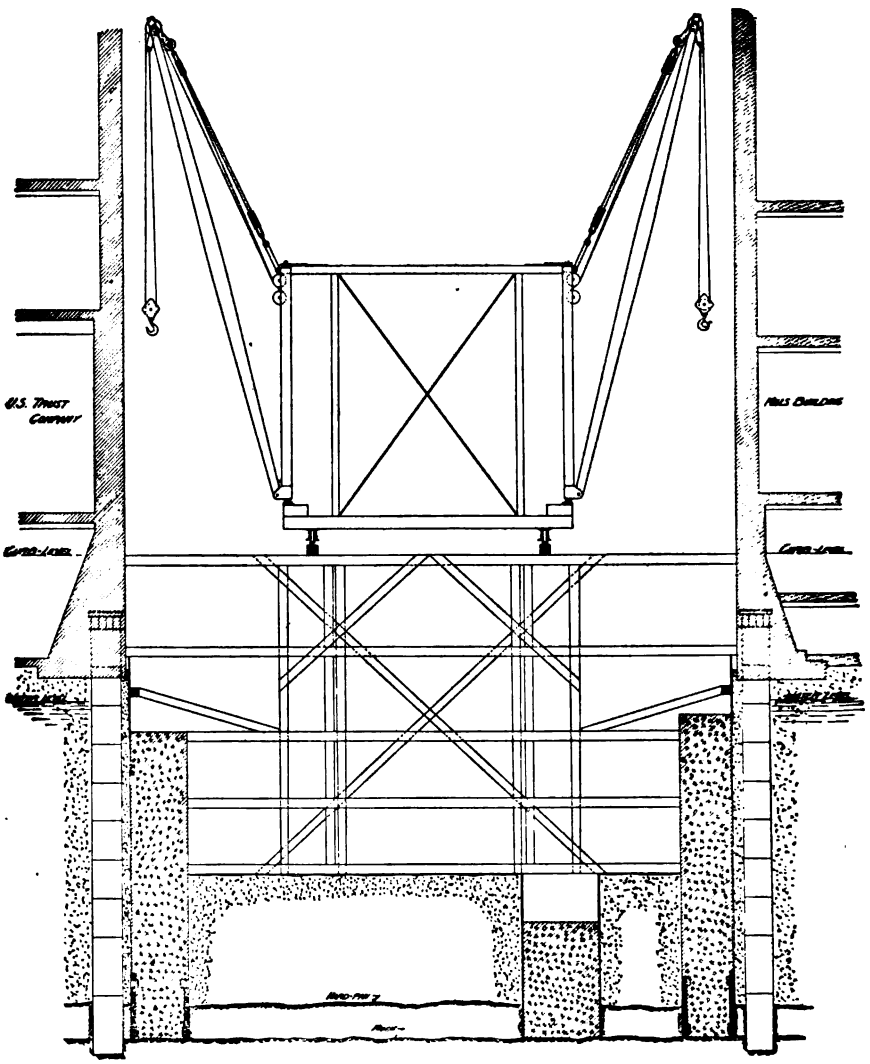


FIG. 6. Section showing caissons sunk to rock and method of cross-bracing the lot

of the well was filled with concrete. The cylinder being firmly cemented in, an air lock was bolted to its top end and things were ready for work below the water line.

The octagonical well was carried down by excavating and by removing the boards *AA*, cutting them to length and nailing them in position at *BB*. This work was all done under pressure. About 40 feet of octagonical well brought the work to the top of the timber caisson proper, where, of course, the core forms stopped. The next step was to excavate the 12-inch strip between the caisson ends, and this was done successfully by means of an ordinary post hole digger. The final task was to concrete the slot between the caissons and the well above. The concreting was done under pressure.

Concluding Remarks.

The foregoing description explains quite clearly the general mode of procedure. There were of course in this work, as is the

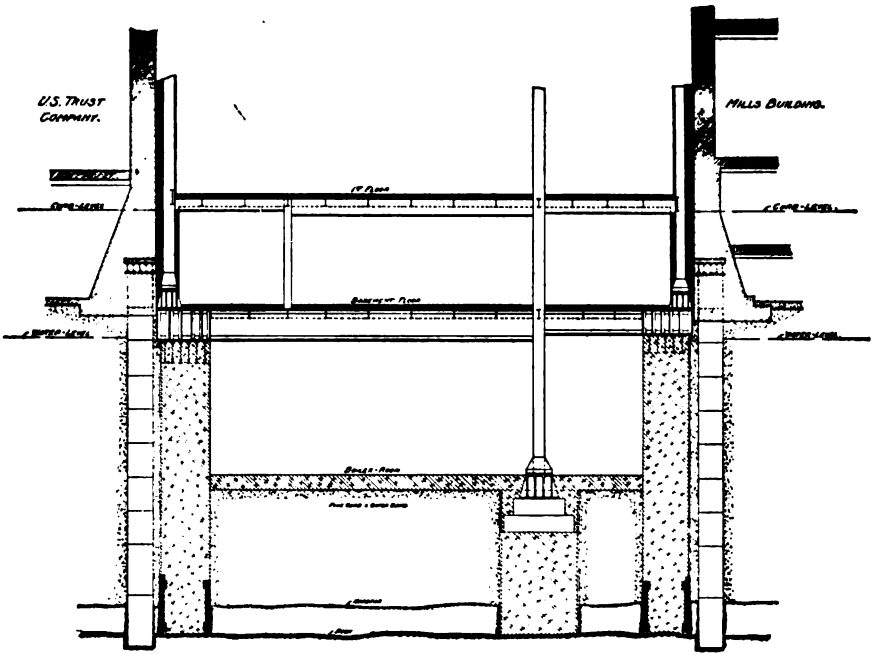


Fig. 7. Section showing finished building below curb.

case in every piece of construction, instances in which special details and methods had to be used for minor tasks. When the wall caissons had been sunk the interior of the lot was excavated to sub-basement level and the interior caissons were put down. Fig. 6 shows the work at this point and is interesting chiefly for showing the arrangement of across-lot bracing adopted as a safeguard until the steel work has been completed as indicated in Fig. 7.

It is the enormous value of building sites in New York City which will always continue to encourage the construction of multiple story buildings in order to increase the number of tenants for

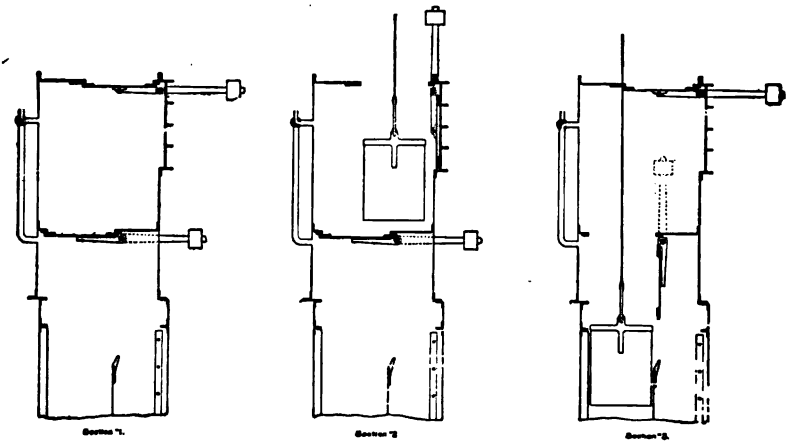


FIG. 8. Sketch showing the method of operation of the improved Moran Air Lock at the Trust Company of America Building.

a given ground area, but of recent years the construction of so many high buildings, especially on comparatively narrow streets has put those of a lesser height to such a disadvantage as to light and air that a new impetus has been given to skyscraper erection.

THE HELION LAMP.

By WALTER G. CLARK and HERSCHEL C. PARKER.

The Helion lamp recently exhibited before the Electrical Engineering Society at Columbia is the result of a number of years of experimenting on materials for incandescent lamp filaments by the writers.

For the past three years the research work has been carried on in one of the research laboratories in Fayerweather Hall. We have for a number of years directed our attention to the development of a material capable of withstanding a higher temperature than the carbon filament used in the incandescent lamp.

The carbon filament at present used, begins to disintegrate or vaporize at a comparatively low temperature when that temperature is produced by a passage of an electric current through the filament, the disintegration beginning between 1400° and 1600° (black body temperature) and by the time 1700° (black body temperature) is reached, the disintegration is so rapid that the lamp fails either through the filament parting or through loss of efficiency due to the disintegration of the filament and the deposit upon the glass of the carbon shot off or vaporized from the filament. With the ordinary 3½ watt carbon filament lamp, the efficient life of the lamp is taken at approximately 600 hours for if the filament does not part at this time, the efficiency has dropped to a point where it is more economical to pay for a new lamp than to pay for the increased current consumption per candle power of light delivered.

Another feature of incandescent lighting is the yellow color of the light which does not give the same color values as daylight. For this reason, colors appear very differently when observed under daylight and the incandescent electric lamp and for the same reason, a lamp giving a light more nearly the color of daylight is a more effective illuminant, as the human eye has become trained to observe and judge colors and illumination under solar light.

As the temperature of a solid source of light increases, the proportion of blue and violet rays increase more rapidly than the longer waves in the red and yellow end of the spectrum. For this reason, the red and yellow becomes less prominent and the light becomes whiter as the temperature increases.

The matter of selective radiation can also be utilized to this end when the selective radiation is in that portion of the spectrum which tends to produce a light approaching a white light. The Welsbach mantle is an excellent example of selective radiation in this portion of the spectrum. The Cooper Hewitt mercury vapor

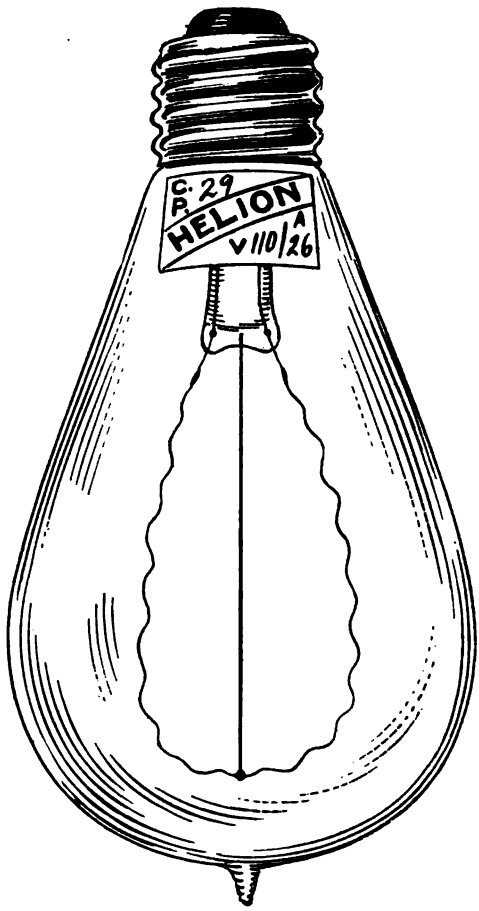


FIG. 1

lamp is another illustration of selective radiation, but from a gas. In this case the selective radiation is in the blue and green end of the spectrum and is lacking in the red and yellow rays so that the light produced is very different from sunlight.

In the development of the Helion filament, we experimented with a great many substances covering practically every element

whose physical properties gave any promise of success, in both metallic and non-metallic elements, and we became convinced that while some metallic substances would withstand the temperature necessary to produce an efficient filament, the low resistance of metals would necessitate that the filaments should be of exceedingly small cross-section in order to secure sufficient resistance to utilize in a lamp the voltage of an ordinary commercial circuit in a lamp of any modern or commercial size.

It is exceedingly difficult to produce a filament from the refractory metals of the small cross-section necessitated by the high conductivity of the metal, and if the filament is produced, it is so attenuated, that it is lacking in structural strength, so that a lamp made from this character of filament would be exceedingly fragile.

Our early observations along this line have been borne out by the difficulty experienced in producing commercially a practicable metallic filament lamp for commercial voltages. In producing a lamp filament from material of lower conductivity or higher resistance, than a metal, it is possible to u-e a greater cross-section for a given degree of incandescence at a given flow of current. Some early experiments by Mr. Clark indicated silicon as a material which gave promise of considerable success although the melting point of this material was comparatively low, but we found that under certain conditions, we were able to produce the material in such a state that it withstood vaporization to a very high temperature and we also found that the radiation in the visible spectrum was greater than that of the ordinary carbon filament.

This increased radiation was not confined to one portion of the spectrum but appeared to extend throughout the entire visible range and gave promise both in the matter of withstanding higher temperature and in giving off a greater percentage of wave-lengths in the visible spectrum than any other material with which we had experimented so far. We have experimented upon this material for several years and after repeated failures, we succeeded in producing the desired material in the form of a filament, possessing the necessary characteristics for use in an incandescent lamp.

The method by which the filament is made is very similar to the one used in treating or flashing the ordinary carbon filament, as we use a base of carbon very similar to the ordinary filament on which we deposit a silicon compound out of gases which are introduced into a flask of the same general type as used in producing a

carbon filament. As soon as the material begins to deposit upon the surface of the filament, the emissivity in the visible range immediately increases and with practically no change in the current consumption, the brilliancy increases very materially. The permanency or life of the filament at the temperature at which we operate is apparently dependent upon the amount of the compound which is deposited upon the filament, but when a sufficient amount is deposited, we still retain a resistance high enough so that we are able to absorb 110 volts in a single corrugated loop. (Fig. 1.)

We have been able to produce lamps of this character for 110 volts consuming 30 watts and giving 30 candle power of light and withstanding a temperature of 1750° (black body measurements) without any apparent disintegration or blackening of the globe.

Another characteristic of the filament is that, while the materia applied to the filament in our treatment has a negative temperature coefficient of resistance and the carbon on which it is deposited has a negative temperature coefficient, the completed filament exhibits this negative temperature coefficient only to about 1400° (black body temperature), at which time it reverses, becomes positive and the positive temperature coefficient increases very rapidly as the temperature increases, so that in this respect, the filament has both the desirable feature of negative temperature coefficient from the central station point of view and a positive temperature coefficient at the temperature at which it is operated, which is valuable from the consumer's point of view, as it enables a lamp to better withstand increases of voltage than would be the case if the temperature coefficient were negative.

The curve shown in figure 2 is plotted from candle power determinations on both the carbon filament and the Helion filament made by the Electrical Testing Laboratories. The temperature determinations were made on the same lamps by means of the Fery absorption pyrometer at Columbia University. It will be noted that the carbon filament lamp at 1380° (black body temperature) required practically 9 watts per candle power, while the Helion filament at this temperature, required but 3½ watts, at 1500° black body temperature, the carbon filaments required 3⅔ watts per candle power, the Helion filaments, 2⅓ watts per candle power.

The carbon filament lamp was rated at 3½ watts per candle power. At this rating the temperature observed on the pyrometer

was 1510° at 1600° the carbon filament lamp required 2¼ watts per candle, the Helion, 1½ watts per candle power.

At this temperature, the disintegration of the carbon filament was so rapid that the efficiency began to fall off very materially

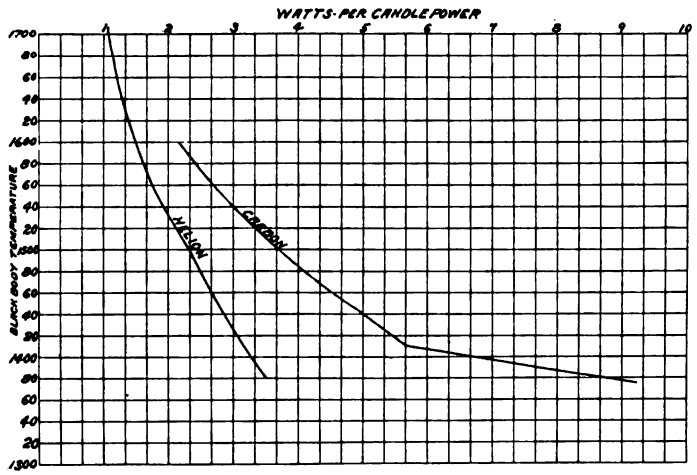


FIG. 2

before another reading could be made, but the Helion filament was carried up to 1700° (black body temperature), at which temperature it consumed 1.07 watts per candle power. In raising the temperature on these filaments from 1400° (black body temperature) to 1600°, the resistance of the carbon filament decreased four ohms, while the resistance of the Helion filaments increased 5½ ohms. From 1600° to 1700° (black body temperature) the resistance of the Helion filament increased nine ohms.

Conclusive life tests have not been completed upon the low candle power filaments of small cross-section, but life tests made upon filaments of greater cross-section for higher candle power filaments at one watt per candle power operated up to, in one case as high as 1,270 hours and on a number of filaments upward of 700 hours, and in each case the drop in candle power was very small, only about 3 per cent. In each case the lamp failed, at or near the joint where the filament was united to the platinum leading-in wires.

We find that the cement used for uniting the filament to the platinum acts upon the filament, so we are at the present time

engaged in the development of a cement for making this joint, which will not act upon the filament, as the lamps of low candle power must necessarily have filaments of reduced cross-section, but the amount of cement used is practically as great as though the filament were of much greater cross-section. For this reason a cement which acts upon and destroys the surface will destroy the small filament much more quickly than it does when used with a filament of greater cross-section, but our experimental lamps produced in the laboratory have operated under laboratory conditions at an efficiency of 1 watt, and less than 1 watt per candle power for a period of time which encourages us in the belief that the helion filament can be made commercially practicable at an efficiency of 1 watt per candle power, with the added advantage that the light given by the Helion lamp is a pure white light, more nearly resembling sunlight than any artificial aluminant yet produced.

It is for this reason that we adopted for the lamp the name Helion, from Helios.

FREDERICK ARTHUR GOETZE

DEAN OF THE FACULTY OF APPLIED SCIENCE.

Frederick Arthur Goetze, dean of the Faculty of Applied Science of Columbia University, was born April 17, 1870. He was in attendance at the Stevens High School during the years 1882–1885; at Cooper Union, 1885–1887; at Columbia University School of Applied Science 1893–1895 as a Special Student. He was engaged in practical work during the years of 1885–1893. From 1895 to 1907 he has occupied the positions of Assistant Superintendent of Buildings and Grounds of Columbia University, being made Superintendent of Buildings and Grounds in 1899, of Barnard College in 1902, of Teachers College in 1903, and of the College of Pharmacy in 1904. He was appointed dean of the Faculty of Applied Science to take office on January 1, 1907, and also to be consulting engineer of the university.

Columbia University awarded Mr. Goetze the honorary degree of Master of Science at its Commencement in 1905.

He is a member of the following societies: American Society of Mechanical Engineers, New York Electrical Society, American Association for the Advancement of Science, Society for the Promotion of Engineering Eduction.

In the President's University Report of 1903, attention was called to "The Office of Dean" and to the necessity of making this office one which should be filled by an administrator who would devote his whole time to the administrative details of the particular school of which he had charge. Under this arrangement the dean was to perform no functions as a teacher, but simply to conduct the operations of the school to the best interests of the university and the school, and in many respects act as a vice-president, or cabinet officer of the university.

In the President's Annual Report of 1905, attention was called to an Amendment to the Statutes which was adopted by the trustees on April 3, 1905, which provided that the deans are to be appointed by the trustees upon the nomination of the president and to serve for an indefinite time. Under this statute "it will be his duty to oversee and guide the work of the several departments and instruc-

tion included in them to make sure that the teaching is properly organized and efficiently given, and to keep constantly before the University the needs and ambitions of the faculty for the improvement and development of their work."

By the appointment of Mr. Goetze to this responsible position the Trustees have carried to completion an idea which is new in the academic world, particularly in the large and complex conditions which exist in a University organization. The duties of a dean are never-ending and consequently if a scholar, or an engineer, or one who desires to devote his energies to scientific research, endeavors to fulfill the duties of a dean and at the same time conduct work in his own particular educational field, he is liable to fail in both. Under the present arrangement much good to the School of Applied Science will undoubtedly result. Proper time can be given by the dean to the consideration of important problems affecting the school, and results which are well known and desired can be carried to a successful conclusion through the constant effort given under the new organization of the dean's office.

Mr. Goetze possesses to a large degree the characteristics of a successful administrator, and the Faculty of Applied Science, as well as the university, is looking forward to an even more successful era in the development of the School of Mines, the School of Engineering, and the School of Chemistry, than has been obtained up to the present time.

G. F. SEVER.

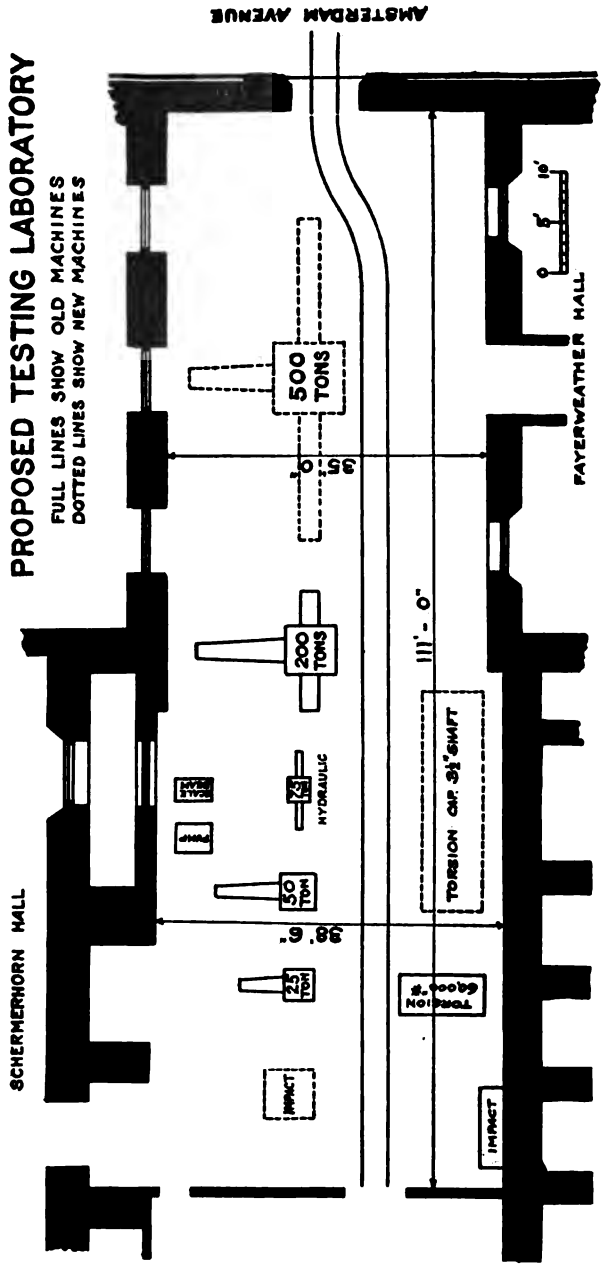
THE PROPOSED TESTING LABORATORY OF THE DEPARTMENT OF CIVIL ENGINEERING.

By WILLIAM H. BURR.

Some important developments in the growth and organization of the Department of Civil Engineering have taken place during the current year. The extension of a number of courses in the Department of Civil and Mechanical Engineering within the past few years has gradually led to certain duplications which have now been eliminated, by giving each of such courses wholly in one department. This improved arrangement of work has brought the mechanical engineers, taking resistance of materials, C.E. 53–54, and hydraulics, C.E. 75, into the department of civil engineering for instruction in those subjects, while on the other hand, Kinematics of machinery and friction of machines, C.E. 79, formerly given by this department will be transferred to that of mechanical engineering. The material increase in size of the corresponding civil engineering classes will necessitate their division into two or more sections so as to reduce the number of students in a class room at any one time, and thus afford opportunity for more efficient individual instruction.

The most important development, however, will result from the transfer of the testing laboratory to the Department of Civil Engineering of which it will hereafter form a part. This laboratory including the new 400,000 pounds Olsen machine recently purchased is now located on the first floor of the engineering building. It is the purpose of the department to secure requisite funds at as early date as practicable to increase largely the equipment of the laboratory both as to the variety of machines and their capacity. In the absence of a suitable building and in the face of the necessity of securing greatly increased accommodation it is proposed to move the testing laboratory into the vault space immediately south of the basement of Schermerhorn Hall on Amsterdam Avenue. This space is 111 feet long by 38 feet wide, and can be extended if necessary.

The plan of development includes the purchase of a 500-ton machine for testing full size compression and tension members 25


PROPOSED TESTING LABORATORY
FULL LINES SHOW OLD MACHINES
DOTTED LINES SHOW NEW MACHINES
AMSTERDAM AVENUE
SCHERMERHORN HALL
FAYERWEATHER HALL
500 TONS
200 TONS
50 TON
25 TON
HYDRAULIC
IMPACT
TORSION
TORSION ON 3½" SHAFT
111'-0"
35'-0"
96'-9"
5'
10'

feet long, a torsion machine of large capacity, an impact machine and the corresponding smaller appliances, tools, electric motors, and other incidental equipment necessary for the complete working installation of the laboratory. The accompanying cut gives a skeleton plan of the proposed arrangement of machines and tramway connection with Amsterdam Avenue.

This laboratory would have the widest range and greatest capacity for all classes of engineering investigation of the physical properties of every kind of structural material of any in the country, and would be second to none in the world. Its usefulness in this line of work alone would be of the highest value in the determination of practical data for a constantly increasing range of construction. It would also be made available to the general public for commercial testing, of which there is a large amount in the city of New York alone, much of it already seeking the testing laboratory of the University, even with its present limited capacity.

It has been carefully estimated that the sum of $50,000 will be required for the purchase of the new machines, appliances and fittings, the removal and reinstallation of the old machines, and the proper preparation of the vault space. An earnest effort is now being made by the civil engineering graduates of the University to raise this fund, and it is hoped that the department may be able to accomplish the desired results in the near future. A committee of the civil engineering graduates of which Mr. D. E. Moran, of the class of '84, is the chairman has taken the initiative in the work of securing the required funds.

ABSTRACTS. — ANALYTICAL CHEMISTRY.

By E. WALLER.

The Use of Filter Tubes for precipitates requiring only gentle ignition is recommended by Penfield and Bradley. (*Am. J. Sci.* [4], XXI., No. 126.) A perforated platinum disc with a wire soldered to the center is the most satisfactory support for the asbestos filtering layer, but coarsely crushed quartz sand from which the smaller particles have been removed by sieving and washing will serve very well. 17 to 20 mm. diameter of the tube is preferable. In case ignition is required, the tube (preferably made from combustion tubing, drawn out as required) may be heated in an inclined position, or the stem passed through a hole made in the bottom of a small porcelain crucible, and the combination heated with a ring burner.

Hydrogen Sulphide. Wilson (*Proc. Lond. Chem. Soc.*, XXII., 312). As ordinarily obtained from FeS, the reagent is very likely to contain As and P compounds. The method described prevents such impurities. A drying tower is filled with granular soda lime or a mixture of $Ca(OH)_2$ and sawdust. A stream of H_2S generated in the ordinary way is passed into this tower until the mass is saturated — a matter readily observed by the progress of the change in color. Then a CO_2 apparatus is substituted for the H_2S generator, and on passing in CO_2 the H_2S is steadily given off, thus; $Ca.HS.OH + CO_2 = CaCO_3 + H_2O + H_2S$.

The flow of H_2S ceases whenever the CO_2 is shut off and can be started again at will.

Preparing Chloric Acid as a Reagent. Bernard (*Ann. Chem. Anal.*, app. XI., 81). Dissolve 800 gm. pure $Ba(ClO_3)_2$ in 1700 c.c. of hot distilled water—filter into a 3-liter flask, cool, and add gradually 243 gm. pure H_2SO_4 of 66 Be. The flask should be immersed in a cooling mixture to prevent any material raise of temperature of the solution. After the $BaSO_4$ has settled — filter through asbestos. The solution has many advantages over a mixture of $KClO_3$ with HCl for oxidizing, etc., *e. g.*, in the Hollard Method for estimation of Sn in bronze, the SnS_2 is readily dissolved by use of $HClO_3$ and HCl, and after boiling out all free Cl and addition of $(NH_4)_2C_2O_4$ can be electrolyzed.

Acetylen as a Reagent. Erdmann and Makowka (*Fres. Zts. Anal. Chem.*, XLVI., 125 et seq.). In a series of articles, the authors show how C_2H_2 may be used advantageously in various separations of the heavy metals, more particularly Cu, Pb, Au, etc. In a way it serves as a substitute for H_2S with those metals.

Standard Sulphuric Acid. Richardson (*J. S. C. I.*, XXVI., 78). Using $Ba(OH)_2$ and weighing the resulting $BaSO_4$ is recommended. 5 c.c. of the diluted H_2SO_4 the Sp. Gr. of which is known are weighed quickly in a platinum dish - phenolphthalein added, and titrated with

a clear saturated solution of $Ba(OH)_2$. The solution is then evaporated to dryness, a Pt cover put on, and the $BaSO_4$ heated to ignition. The weight of $BaSO_4$ thus found should correspond to the Sp. Gr. The strength thus found can be used as a basis for the calculation for dilution, etc.

Standardizing with Metallic Magnesium. Vesterberg (*Fres. Zts. Anal. Chem.*, XLVI,, 81). The metal being non-hygroscopic, and easily obtained in pure form, and capable of being kept in that state for practically indefinite periods, as well as the fact that it completely neutralizes acids, renders it useful for this purpose. The author takes an amount of the Mg ribbon (after thorough cleansing) which will serve to neutralize about $\frac{9}{10}$ of the acid to be used, and treats it with the acid in a flask, which is placed on the water bath. Two hours may be necessary to dissolve the Mg. The solution is finally boiled to insure the solution of the last portions of Mg. The neutralization is completed with $Ba(OH)_2$ solution and phenolphthalein. H_2SO_4 is more easily standardized by this means than HCl, the tendency to formation of basic salts being less. Incidentally the author found that material errors in standardizing may be caused by the action of some of the acids on the glass of the flasks or beakers.

Acidimetric Estimation of Phosphoric Acid. Schucht (*Zts. angew. Chem.* XIX., 1708). With methyl orange indicator the results are much influenced by the degree of dilution. Also addition of NaCl increases the acid titre perceptibly with pure H_3PO_4, still more when CaH_2PO_4 is in the solution. The reason appears to be attributed to differences in ionization.

Free Mineral Acids in Presence of Acetic. Corsini (*Giorn. Farm. Chem.*, LV., 200). For this purpose methyl violet has been used quite generally; the author finds that Tropæolin OO. in alcoholic solution is more distinct and sensitive. The change of color is from yellow to reddish violet.

The color change is produced by:

In water only.	In presence of acetic.
.1 in 20,000	under 0.5 in 1,000 of H_2SO_4.
1.1 in 10,000	under 1.5 to 2 in 1,000 of HNO_3.
2.5 in 10,000	under 2 to 2.5 in 1,000 of HCl.

Reagent for Potassium. Schlicht (*Chem. Ztg.*, XXX., 1299). The "yellow precipitate" (ammonium phosphomolybdate) is fused with Na_2CO_3 and $NaNO_3$. The melt after cooling is dissolved in water and acidified with HNO_3. This solution gives a yellow precipitate with even very dilute solutions of K salts.

Potassium — Phosphotungstic Test. Meyer (*Chem. Ztg.*, XXXI., 158). In rock salt for instance, 20 gm. of the sample are dissolved in water, and the solution made up to 100 c.c. On mixing 1 c.c. of the clear solution with 1 c.c. of a 20 per cent. solution of sodium phosphotungstate, a precipitate will indicate as little as 0.7 per cent. of KCl. A solution of the rock salt of between 10 and 20 per cent. strength will

show 1 per cent.; one between 5 and 10 per cent. strength will show 2.5 per cent. and 2.5 to 5 per cent. strength will show 4 per cent. KCl. The reagent gives no precipitate with Na, Mg or Ca salts.

Distinguishing Dolomite from Calcite. Cornu (*Centr. Min.*, 1906, 550). On shaking the finely pulverized mineral with water containing a little phenolphthalein, calcite imparts a strongly alkaline color to the indicator, whereas dolomite affords only a faint coloration.

Separating Barium from Calcium. S. Krabal and Artmann (*Zts. Anal. Chem.*, XLV., 584). The metals should be in the form of chlorides, and so far diluted that 30 c.c. of the solution contains not over 0.1 gm. CaO. Heat to boiling, and precipitate with N/2 H_2SO_4. Filter and wash the precipitate, and then fuse with Na_2CO_3. Treat the melt with hot water, and then add $HC_2H_3O_2$ in excess. The residue will be pure $BaSO_4$. The solution may be added to the filtrate from the sulphate precipitation, and Ca determined in the combined solutions.

Ferrous Iron. Rupp and Horn (*Arch. Pharm.*, CCXLIV., 571). The oxidation of ferrous iron by I is rapidly effected in presence of caustic alkali. To a neutral or slightly acid solution of the sample is added a measured amount of N/10 I solution in excess, following that by rendering the mixture decidedly alkaline with caustic alkali (about 5 per cent. strength). After the lapse of some minutes for the reaction to take place, glacial acetic acid equal in volume to that of the caustic is added to render the mixture acid (or $H_2C_2O_4$, half as many gms. as the number of c.c of alkali). After 5 to 10 minutes the volume is made up to 100 c.c. and the excess of I titrated back with standard $Na_2S_2O_3$ (1 c.c. N/10 I = 0.005588 Fe). NH_4 salts interfere, Mn and ferric do not.

Zinc — Precipitation of Small Amounts. Bertrand and Javillier (*C. Rend.*, CXLIII., 900). The method will serve for the identification of one part Zn in 500,000 of water. To 500 c c. of the solution add a little milk of lime or 50 c.c. lime water, and 10 to 15 per cent. conc. NH_4OH. Filter, and boil out NH_3. The compound which forms is $Ca(O.ZnOH)_24H_2O$ together with some $CaCO_3$. Filter through a small filter, dissolve in HCl, evaporate to dryness, take up with water, add excess of NH_4OH, and separate Ca by oxalate. In the filtrate the Zn can be determined by evaporation with excess of H_2SO_4 and weighing as Zn SO_4. The results for quantitative estimation should be corrected by deducting the amounts left in a blank experiment. If qualitative results only are desired, the ferrocyanide test may be used.

Zinc — Na_2S Titration. Deckers (*Bull. Soc. Chim. Belg.*, XX., 164). The amounts of NH_3 or NH_4 salts in the solution have a decided influence on the results. The solution therefore should be standardized under known conditions in these respects, and titrations made under like conditions.

Zinc — Ferrocyanide Titration. Seaman (*J. Am. Chem. Soc.*, XXIX., 205). A study of the conditions influencing the results. Using a volume of 150 c.c. containing about 0.185 gm. Zn, the following points were noted:

An excess of HCl up to 10 c.c. has no perceptible effect. Beyond this limit high results may be obtained especially at higher temperatures.

Presence of $KClO_3$ gives high results, especially at the higher temperatures.

Increase of acid with constant amounts of $KClO_3$ increase the consumption of ferrocyanide.

NH_4Cl helps to settle the precipitate, and so far as tried does not seem to have any disadvantageous effect.

Fe, Cu, Pb, Cd, Sn and Mn in the solution cause high results. Al and Ca are without influence.

Different amounts of Zn in a uniform bulk of solution showed that a slightly different factor should be used according to the proportion of Zn present.

The presence of free Br was found to be detrimental to accuracy. A modified method is proposed: Treat 0.5 gm. of ore in a casserole with 7 c.c. conc. HNO_3 adding 7 c.c. conc. HCl, digest at not over 60° for 15 minutes, then add 7 gm. NH_4Cl and evap rate to dryness; make alkaline with 5 c.c. NH_4OH, add 15 c.c. Br water, boil 3 minutes — filter hot, into a 400 c.c. beaker; wash three times with hot solution of NH_4Cl containing NH_4OH; make the solution weakly acid with HCl; introduce a slip of Al foil, and boil 3 minutes; remove the foil, wash it off, and heat to boiling for titration; filtering off the precipitated metals is not necessary. Add 5 c.c. conc. HCl, and begin the titration at 85° finishing before it falls to 40° C. — H_2O_2 may be substituted for the Br water.

Volumetric for Zinc. Muller (*Bull. Soc. Chem.* [4], I., 13). Modification of Pouget's method. The Zn solution is neutralized with NH_4OH or if in an ammoniacal solution, the excess of NH_3 is boiled out. An excess of $NaC_2H_3O_2$ is added then it is slightly acidified with acetic, and thereupon saturated with H_2S. After complete precipitation of the Zn, the excess of H_2S is driven out by passing CO_2 through the solution heated over the water bath to about 50° — applying an exhaust at the same time to the flask. Under these conditions, about half an hour suffices to remove all H_2S. If dilution is necessary at this point, boiled water should be used. HCl sufficient to dissolve the ZnS is then added followed immediately by an excess of standard I solution. The flask is then closed and well shaken, and after standing the excess of I titrated with standard $Na_2S_2O_3$.

Zn minerals and ores, should be decomposed in the usual manner with acids, and after separating members of the H_2S group, Fe and Mn are precipitated out by use of NH_4OH and H_2O_2. After boiling the filtrate to expel the excess of these reagents the process can be conducted as above.

Zinc Ores. Report of Subcommittee on Zinc ore analysis (*J. Am. Chem. Soc.*, XXIX., 262). The modified Waring method is recommended. For this a weighed amount is brought into solution by any satisfactory means, a sulphate solution being made the resultant outcome. If HNO_3 has been used, all traces of it must be removed. Dissolve the residual sulphates in 25 to 40 c.c. of water, and add enough H_2SO_4 to bring the free acid up to 10 or 12 per cent. Introduce Al foil, and boil ten minutes. Filter and wash through a filter containing a bit of Al foil, into a beaker containing also a piece of the same metal.

Cool — add methyl orange and neutralize with $NaHCO_3$ to a light straw color. Add drop by drop, dilute HCl (1:6) until the pink color is just restored, and then 5 drops more. (If NH_4CNS is unnecessary the HCl may be replaced by formic acid.) Dilute to 100 c.c. for every 0.1 gm. Zn presumed to be present, add 2 to 4 gm. NH_4CNS, remove the strip of Al, heat nearly to boiling, and saturate with H_2S. Allow the ZnS (which should be white) to settle, filter and wash well with hot water. Treat, filter and precipitate with 8 or 10 c.c. conc. HCl in 30 to 40 c.c. water. In the solution determine Zn preferably as $Zn_2P_2O_7$ (gravimetrically). The volumetric process with ferrocyanide is not recommended indiscriminately. The bulk of solution, amount of free acid, and various other details, all have an influence on the results, and in the hands of those who maintain uniformity in those data with especially reference to the proportions of Zn present, and the details of standardizing, very accurate results can be obtained. In a laboratory for general work where Zn determinations are somewhat infrequent, accurate results by the ferrocyanide titration may fail to be attained.

Separation of Zinc from other members of the group. Funk (*Frs. Zts. Anal. Chem.*, XLVI., 93). An investigation of different methods indicates that in neutral or nearly neutral solution containing alkaline acetate, as also in presence of a little free acetic, the separation by H_2S is imperfect. Some of the other metals begin to precipitate also before all Zn has been converted to ZnS. Also, the precipitates are often slimy. The formic separation succeeds well when the solutions are well diluted: $NaCHO_2$ should be present in the proportion of 0.2 gm. of the salt to every 0.1 gm. of Zn. Not over 3 per cent. of free $HCHO_2$ should be present as a maximum.

Treadwell's "salting out" process (*Zts. Anorg. Chem.*, XXVI., 104) requires that the metals shall be present as chlorides or sulphates; the sum of metallic oxides should be about 0.25 per cent. of the solution; then 8 to 10 drops of double normal HCl should be added for every 0.1 to 0.3 gm. Zn present, and the same amount of a 2 per cent. solution of ammonium sulphate or chloride; the solution should be at about 50° C. when the H_2S is passed in; the ZnS allowed to settle while keeping the solution warm, and wash with H_2S water containing 2 per cent. of ammonium salt. This method was found also to be satisfactory. The choice between the two depends upon the relative proportions of the metals present, and sometimes on other conditions. It may be found more expeditious in certain cases to precipitate out all the metals by Na_2CO_3 and to dissolve up in acid (formic or mineral acids) before attempting the separation. To separate from Co the more dilute solutions are always necessary.

Formate Process for Separating Ferric Iron from other members of the group. Funk (*Zts. Anal. Chem.*, XLV., 489). Add NH_4Cl in the proportion of 2 mols. to every atom of Fe assumed to be present. Evaporate on the water bath nearly to dryness. Take up with water and add NH_4CHO_2 to the extent of about twice as much as should serve to combine with the Fe. Dilute considerably, though *not* beyond the ratio of 1 of NH_4CHO_2 in 800. Heat until a precipitate begins to

form, and then neutralize with weak NH_4OH. Heat for a minute and filter off basic ferric formate. Wash with dilute NH_4CHO_2. In the filtrate all the $HCHO_2$ can be expelled by heating with a little excess of H_2SO_4. In that respect the process is superior to the basic acetate method.

Cobalt — Delicate Test. Alvarez (*Ann. Chim. Anal.* XI., 445). A very minute amount of Co as chloride or sulphate, when added to a large excess of boiling strong solution of KOH or NaOH gives a blue color which is destroyed by dilution. Ni salts in larger proportion give a blue of different quality which becomes reddish when heated.

Cobalt Separations. Funk (*Fres. Zts. Anal. Chem.*, XLVI., 1). Co can be separated from Mn by means of KNO_2 in the same manner as from Ni provided a nitrate or chloride solution is used. A sulphate solution gives unsatisfactory results. From Fe the separation by nitrite is unsatisfactory unless both metals are present in very small amounts. Basic Fe compounds will separate along with the nitrite precipitate in any case, the results being the poorest in sulphate solutions.

Sodium Chloride in Commercial Tin Salts. Heermann (*Chem. Ztg.*, XXXI., 27). The solution of tin salt should be of Sp. Gr. about 1.5 to 1.7. On adding absolute alcohol which has been saturated with HCl gas, the NaCl precipitates even when as little as 0.1 per cent. is present. The precipitate can be filtered off, washed with absolute alcohol, and determined by weighing or by titration. Aqueous HCl does not give a precipitate unless the proportion of NaCl is 1 per cent. or over. 96 per cent. alcohol gives no precipitate unless 6 to 8 per cent. of NaCl is present.

Antimony — Volumetric. Rowell (*J. S. C. I.*, XXV., 1181). The method depends upon reduction to the triad form by SO_2 and titration with standard $KBrO_3$ in HCl solution until the excess destroys the color of methyl orange. The $KBrO_3$ solution is standardized by means of an As_2O_3 solution. The process is a modification of Gyory's method. The solutions to be prepared are:

As Solution for Standardizing. 0.8236 gm. pure dry As_2O_3 dissolved first in 5 c.c. of 10 per cent. NaOH, then acidified with 5 c.c. conc. HCl and made up to 500 c.c.; 50 c.c is equivalent to 0.1 gm. Sb. The solution will keep about a fortnight.

Indicator. 0.1 gm. methyl orange in 100 c.c. of hot water.

Bromate Solution. 1.3926 gm. per liter is the theoretical quantity, but as the so-called "pure" salt always contains a little KBr, 1.41 gm. per liter is recommended. The solution should be standardized every week, using 50 c.c. of the As_2O_3 solution with 20 c.c. conc. HCl. A solution four times this strength may be used if one is dealing with comparatively high percentages of Sb.

Bromine Solution (for dissolving). 35 c.c. pure Br shaken up with 250 c.c. conc. HCl.

Process: An amount of the ore or alloy containing not over 0.15 gm. Sb is treated in a 500-c.c. beaker with 25 c.c. conc. HCl and 5 c.c. of the Br solution. The beaker is then kept hot, but not boiling, lest the Br be driven off before solution has been effected. With Sb compounds that resist this treatment fusion with NaOH and subsequent

acidification with HCl may be necessary. In either case, after bringing all Sb into solution, add 3 or 4 gm. fresh crystals of Na_2SO_3, and evaporate down low with watch glass cover. (The HCl should be in sufficient excess to more than combine with all the Na in the sulphite.) If As is present to the extent of 2 or 3 per cent., add 5 c.c. SO_2 solution and evaporate again to expel all As, then add 20 c.c. conc. HCl and 40 c.c. of hot water, rinse down the sides and cover, and boil one minute to remove SO_2. Then run in the standard $KBrO_3$ solution at the rate of about 30 c.c. in 50 seconds stirring all the time. The temperature should not fall below 60° C. during the titration. If any $PbCl_2$ separates, heat to bring it into solution. The indicator should not be added until near the end-point, when two drops are added, and the $KBrO_3$ run in until the color is destroyed. A blank test should be frequently made to correct the burette readings.

Fe influences the result but little. Cu gives the most interference. If it amounts to about 1 per cent. deduct 0.012 per cent. (apparent) Sb. for every 0.1 per cent. Cu present. In the case of larger amounts of Cu, dissolve the sample in HNO_3, evaporate to dryness, boil up with 50 c.c. of 1 per cent. HNO_3, decant through a filter, boil up with 30 c.c. of 5 per cent. NH_4NO_3, wash two or three times with the same, ignite and fuse the residual Sb_2O_4 with NaOH, bring into solution, and treat as previously described.

J. B. Duncan (*Ch. News*, XCV., 49) describes identically the same process, with the exception that he recommends a $KBrO_3$ solution twice as strong as the above. He does not find that Cu interferes unless the proportion is large (25 per cent.). 25 per cent. of Fe renders the end point obscure.

Separating Antimony and Tin. Czerwek (*Zts. Anal. Chem.*, XLV., 505). Dissolve 0.5 gm. at 40 to 50° C. in a mixture of 15 c.c. conc. HNO_3, 15 c.c. H_2O and 6 gm. tartaric. Then heat to boiling and add a slight excess of H_3PO_4 solution of Sp. Gr. 1.3. Sn is completely precipitated as phosphate. Dilute with 300 c.c. of boiling water, filter and wash with hot dilute $NHNO_3$. In the filtrate, obtain the Sb by neutralizing with NH_4OH and $(NH_4)_2S$ and acidifying with acetic. The Sn precipitate is dissolved in warm $(NH_4)_2S$ which is then acidified in the cold with H_2SO_4, to separate the SnS_2.

Antimony and Tin in alloys, etc. W. H. Low (*J. Am. Chem. Soc.*, XXIX., 66). Solution is effect by heating with $KHSO_4$ and conc. H_2SO_4, the presence of HCl being carefully avoided at this stage of the operation. Alloys can be treated directly. If the operation is performed on the mixed sulphides separated from a solution containing HCl, all chlorides must be carefully washed out. After the material has been completely brought to the proper condition, the Sb will be as triad, the Sn as tetrad and all SO_2 and free S boiled out or oxidized. Tartaric may be added for purpose of reduction if necessary — *i. e.*, in the case of presence of much Sb. In that case heating must be continued until all C has been oxidized. After cooling sufficiently bring into solution with about 50 c.c. water and 10 c.c. conc. HCl, and heating. Dilute and add more HCl so that there is full 20 c.c. conc. HCl in 200 c.c. of the solution. Cool completely and titrate with standard permanganate

(0.1202 gm. pure Sb in standardizing should take 20 c.c. $N/10$ permanganate). The end point is sharp, but the color does not remain long.

Pour the solution into a 500 c.c. round bottomed flask, rinsing with conc. HCl so as to bring the proportion of conc. HCl up to fully 20 per cent. Add about 1 gm. powdered C.P. metallic Sb to reduce the Sn. Stand the flask on a steam bath for about 15 minutes. Then connect with an apparatus giving a rapid stream of CO_2 gas, and heat to boiling with naked flame, heating the sides rather than the very bottom where the Sb lies, on account of the danger of unequal heating. Boil for 2 or 3 minutes, than cool as rapidly as possible, keeping up a strong current of CO_2 to avoid back pressure. Withdraw the cork and tube carefully to avoid introduction of air, introduce 5 c.c starch solution and titrate with $N/10$ I solution, shoving the tip of the burette well into the flask. The end point should be sharp and positive if the flask is gently agitated during the addition. (0.119 gm. pure Sn in standardizing should require 20 c.c.)

Arsenic and Antimony in Ores. A. H. Low (*J. Am. Chem. Soc.*, XXVIII., 1715). Treat 1 gm. of ore in a 150-c.c. flask with 7 gm. $KHSO_4$, 10 c.c. conc. H_2SO_4 and 0.5 gm. tartaric. The latter is to keep elements in the *ous* form. Heat over a free flame cautiously at first — finally with the full heat of the burner, manipulating the flask with a holder, until all free sulphur has been removed, and the carbon all oxidized. During cooling turn the flask about so as to spread the contents in a thin layer against the sides. Then add 50 c.c. water, 10 c.c. conc. HCl, and 2 or 3 gm. tartaric. Heat to affect solution. Do not boil for fear of loss of As. Filtration at this point is advisable though not necessary. Dilute to 300 c.c., and pass H_2S through the warm solution. Filter washing with H_2S water. Rinse precipitate into a beaker with as little water as possible — add colorless KHS, pour through the last filter into a flask and treat with about 3 gm. $KHSO_4$ and 10 c.c. conc. H_2SO_4 boiling down over a free flame until free S is removed. Cool in the same manner as before, then add 25 c.c. water and 10 c.c. conc. HCl. Heat to effect solution, then cool under the tap. Add 40 c.c. conc. HCl and pass H_2S. As only will precipitate. In the filtrate Sb may be separated by diluting with double its volume of warm water, and passing H_2S. Dissolve the Sb_2S_3 after filtering off with $KHSO_4$ and H_2SO_4 as before. After removing all free S and SO_2 by boiling, dilute, add HCl, cool, dilute to 200 c.c. and titrate with standard permanganate.

The As_2S_3 is brought into solution similarly with $KHSO_4$ and H_2SO_4 after cooling and diluting the solution is rendered slightly alkaline with NH_4OH then barely acid with HCl, $NaHCO_3$ is added, and the As titrated with standard I solution.

Colorimetric for Gold. Maxson (*Am. J. Sci.*, XXI., 270). The precipitation of finely divided Au by aqueous solution of acetylene affording a pink to red coloration, was found to be available for quantitative colorimetric estimations. The water forming the solutions has to be free from any electrolyte or the coloration will change to the blue modification. In the first experiments a Gallenkamp colorimeter was

used. Later, a modification of Penfield's apparatus proved more convenient.

The limit of accuracy appeared to be in solutions containing 0.00001 gm. Au in 1 c.c.

Control of Electric Copper Refining. Koch (*Fres. Zts. Anal. Chem.*, XLVI., 29). *Free Acid.* The Kieffer solution has been unfavorably regarded by some, because of a tendency of the standard solution to cloud on standing. If crystallized cuprammonium sulphate — $CuSO_4$, $4NH_3$, H_2O — is used, 65 gm. per liter affords a normal solution and the addition of 6 gm. $(NH_4)_2SO_4$ will cause it to keep perfectly.

Copper Titration. The most convenient method is the titration with standard Na_2S in acid solution to which chloroform has been added. The CuS is caught by the chloroform on agitation, and the solution is thus quickly cleared — so that the end point (absence of precipitation) can be readily seen.

Arsenic. 30 gm. of the copper is dissolved in 300 c.c. of HNO_3 (Gr. 1.2), and evaporated low to drive off the excess of acid. Dilute to 1 liter, add NH_4OH in excess, and then 10 c.c. of cold saturated Na_2HPO_4 and 20 c.c. magnesia mixture. Allow to stand 3 or 4 days — then filter. Thorough washing is not only unnecessary, but unadvisable. Dissolve in H_2SO_4, evaporate to fumes, add about 20 gm. coarsely pulverized $FeSO_4$ and not until the mixture is thoroughly cooled should 70. c.c. conc. HCl be added. The mixture for distillation should have a density of fully 50° Be. The management of the distillate containing the As requires no description.

Mercury-Volumetric. Rupp (*Ber.*, XXXIX., 3702). The sulphocyanide titration is only applicable to combinations of Hg with oxygenated acids. A method applicable to halogen compounds such as $HgCl_2$ is given. To the solution of the salt (so diluted that about 0.2 gm. are contained in 25 to 50 c.c.) is added KI in sufficient excess to dissolve the precipitate which first forms. The solution is then made alkaline with NaOH or KOH and 2 or 3 c.c. of 40 per cent. formaldehyd in 10 c.c. of water is added. On stirring finely divided Hg is almost instantaneously precipitated. After 30 to 60 seconds, acidify with acetic, and add a measured quantity of N/10 I solution. HgI_2 is formed by stirring, and the excess of I is titrated by standard $Na_2S_2O_3$ solution.

Beryllium Estimation. Parsons and Barnes (*J. Am. Chem. Soc.*, XXVIII., 1589). A brief review of the different processes for separation of BeO from Al_2O_3 is given together with references. It was found that by adding approximately 10 per cent. of solid $NaHCO_3$ to the neutralized solution of mixed Be, Fe and Al salts (10 gm. to 100 c.c.) and bringing quickly to a full boil (no more), essentially all of the BeO remained in solution. A repetition of the treatment on the precipitate (redissolved in HCl) gave a satisfactory quantitative separation. In the combined filtrates HCl was added, the CO_2 boiled out and the Be precipitated by NH_4OH. The precipitate required to be washed with $NH_4C_2H_3O_2$ solution to prevent it from assuming a colloidal condition.

Beryllium — Separation from Aluminum and Determination. Glassmann (*Ber.*, XXXIX., 3366 and 3368). The present methods are

enumerated as: $(NH_4)_2CO_3$ treatment of the NH_4OH precipitate; Havens method (*Zts. Anorg. Chem.*, XVI., 15) depending on the solubility of $BeCl_2$ in a mixture of equal volumes of concentrated aqueous and ethereal solution of HCl; and that of Penfold and Harper (*vide* Crookes Select Methods) by use of alkalies.

The author's method is by $Na_2S_2O_3$. The solution is nearly neutralized with Na_2CO_3, an excess of $Na_2S_2O_3$ added, and the mixture boiled until all odor of SO_2 is gone, and then heated for half an hour longer on the water bath. Al_2O_3 is thus completely precipitated. In the filtrate after destroying the excess of $Na_2S_2O_3$ by heating with HCl, the BeO may be precipitated with NH_4OH or better with KI + KIO_3 mixture. NH_4OH affords a slimy precipitate which is very troublesome to filter or to wash. In a neutral or weakly acid solution the above reagent acts thus: $3BeSO_4 + 5KI + KIO_3 = 3Be(OH)_2 + 3K_2SO_4 + 3I_2$.

The reagent is made by mixing equal volumes of a 25 per cent. solution of KI and a saturated solution of KIO_3 (about 7 per cent.). Add an excess of the reagent (in the cold). Allow to stand 5 minutes and then remove free I by exact addition of 20 per cent. $Na_2S_2O_3$ solution. Test to see that the reaction is complete, warm for half an hour on the water bath, and then filter and wash with boiling water.

Friedheim (*Ber., ib.*, 3868) remarks that this method is not new, having been proposed in 1864 by Joy. Zimmermann later on (1888) found that the method was only successful when the two elements were present in approximarely equal quantities. Also the precipitate obtained in Al salts by use of $Na_2S_2O_3$ is not $Al_2(OH)_6$ but contains basic sulphite and sulphate.

Analysis of Wulfenite. Gilbert (*Zts. off. Chem.*, XII., 263). Pulverize finely, place 1 gm. in a porcelain boat, introduce into a combination tube and roast in a slow current of air for 4 hours. Rinse out the combustion tube with moderately conc. NH_4OH, shake the contents of the boat into the solution, and boil for 3 hours. Filter, and evaporate the filtrate to dryness in a weighed Pt dish finally igniting cautiously at not over dull red heat, until a constant weight is obtained. The MoO_3 thus obtained is likely to contain some SiO_2 or other impurity. Boil up with NH_4OH filter, and ignite and weigh the residue and deduct. The insoluble portion of the roasted ore holds back a little Mo. Fuse with mixed carbonates, treat the melt with water — adding a little alcohol to remove Mn, filter, and in the filtrate, acidify, reduce with Zn, and titrate with permanganate.

Molybdenum in ores and ferromolybdenum. Darrock and Meiklejohn (*Eng. and Min. Jour.*, LXXXII., 818). The method is the reverse of the molybdate titration of lead, the standard solution containing about 25 gm. $Pb(C_2H_3O_2)_2$ per liter with a little free acetic Titration is performed in a boiling hot solution and a spot test with tannic acid solution is used to determine the end-point. To obtain the solution 0.5 to 1 gm. of the original material (well pulverized) is fused with 4 gm. Na_2O_2 the melt being kept at a low red heat for 3 to 5 minutes. When cold — dissolve in 150 c.c. of hot water — filter and wash thoroughly — acidify with acetic, bring to a boil and titrate.

Tungstic Acid in Wolframite, etc. Watts (*C. News*, XCV., 19).

Treat 1 gm. of the finely pulverized ore with 50 c.c. conc. HCl and 15 c.c. conc. HNO_3 heating for about 4 hours just short of boiling, so that at the end of that time the solution will be 10 to 15 c.c. Add 50 c.c. hot water — allow to settle for about 30 minutes. Decant on a filter, and wash twice by decantation, using each time 50 c.c. hot water and 5 c.c. conc. HCl. Treat the residue in the beaker, with 25 c.c. of NH_4OH (1 : 10) to which a little NH_4Cl has been added. Pass the solution through the filter into a weighed porcelain or platinum dish, washing well with the NH_4OH solution. If the residue is not white the treatment with aqua regia must be repeated. Evaporate the solution to dryness, heat up slowly at first — finally to the full heat obtainable with a good Bunsen burner. Some volatilization of the WO_3 may occur if the blast is applied. Weigh WO_3.

Niobium and Tantalum in presence of Titanium. Warren (*Am. J. Sci.* [4], XXII., No. 132). The usual method — fusion with $KHSO_4$ and leaching out with water, it being assumed that only Ti is dissolved out, was found to be unsatisfactory as more or less Nb and Ta also dissolve out with the Ti. A. A. Noyes also records this fact.

The method of Osborne, which consists in reducing Nb and Ti in a HF solution of the three by means of Zn, titrating with permanganate, determining Ti colorimetrically with H_2O_2 and estimating Ta by difference was found to give untrustworthy results. The author declares that at the present time no accurate method of estimation is known.

Chlorides — Volhard's method. Rosanoff and Hill (*J. Am. Chem. Soc.*, XXIX., 269). On investigating this method — precipitating by excess of standard $AgNO_3$, and then *without filtering* titrating the excess of $AgNO_3$ with standard NH_4CNS, with $Fe_2(SO_4)_3$ as indicator, it was found that it is absolutely necessary to filter off the AgCl formed before proceeding to the NH_4CNS titration. AgCl reacts rapidly with the $Fe(CNS)_3$ (indicating the end point). In the case of bromides and iodides the corresponding change does not occur with sufficient rapidity to influence the results.

Chloride in Waters — Volhard method. Shutt and Charlton (*Trans. Royal Soc. of Canada*, XI., 67). The solutions required are:

$AgNO_3$ solution of which 1 c.c. = 0.001 gm. Cl.

KCNS solution of corresponding strength. (NH_4CNS cannot be used.)

HNO_3; 3 vols. of acid to 1 of water. This should be boiled to expel N oxides, and kept in the dark.

Indicator — made by oxidizing $FeSO_4$ with HNO_3, evaporating to dryness repeatedly with conc. H_2SO_4 to expel N oxides, and adding ferric carbonate to neutralize the excess of acid, finally filtering.

To 100 c.c. of the water add 5 to 10 c.c. of the HNO_3, then add from graduated pipette a slight excess of the $AgNO_3$ solution, after standing a short time, filter and wash into a porcelain dish. Add 1 c.c. of indicator and titrate back with the standard KCNS.

In the results quoted, the method usually gave slightly lower results than with the ordinary chromate indicator.

In peaty waters or when the Cl is very small, the method will often serve when the chromate titration fails. It is not proposed as a substitute, but as supplementary in such cases.

Iodine in Presence of Chlorine and Bromine. Rupp and Horn (*Arch. Pharm.*, CXLIV., 405). 0.2 to 0.5 gm. of the sample dissolved in about 50 c.c. of water, is placed in a stoppered flask, and about 25 c.c. dilute H_2SO_4 and 3 gm. $H_2C_2O_4$ are added, then about 10 c.c. of a 1 per cent. permanganate solution, and the stoppered flask is allowed to stand (with occasional shaking) for 3 hours. Then 1 gm. KI is added, and the free I titrated with $N/10$ $Na_2S_2O_3$. Should decidedly less than 10 c.c. of the $Na_2S_2O_3$ solution be used, the operation should be repeated, using either more of the substance or less of the permanganate.

Fluorine Iodometric Estimation. Hillman (*Am. J. Sci.* [4], XXII., 383). SiF_4 when freed from a material under examination by the joint action of SiO_2 and conc. H_2SO_4, is passed into water. The solution when mixed with potassium iodate-iodide and distilled, affords I proportionate to the amount of F present, atom for atom.

Hydrofluosilicic Acid. Schucht and Möller (*Ber.*, XXXIX., 3694). With phenolphthalein indicator, especially when hot, the titration progresses according to the equation: $H_2SiF_6 + 6KOH = 6KF + H_4SiO_4 + 2H_2O$. Offerman's assertion is that K_2SiF_6 is formed. Such seems to be the case though only momentarily when cochineal or methyl orange is used as indicator, but with these the dissociation progresses slowly toward the last, and the change point is not sharp. This difficulty may be avoided by adding to the solution an excess of neutral $CaCl_2$ solution. The $CaSiF_6$ dissociates quickly, and a sharp end reaction is obtainable. With such addition of $CaCl_2$, methyl orange in the cold is the best indicator.

Decomposing Silicates. Hinden (*Zts. f. Anal. Chem.*, XLV., 332). 1 gm. of the pulverized silicate is treated in a platinum dish with 15 c.c. conc. HF. After moistening with water, it is then evaporated to dryness, 5 to 10 c.c. of HCl and 10 c.c. of HF are then added, and it is again evaporated. At this point the bases are now in the form of fluorides or silico-fluorides. To convert to chlorides, evaporate six successive times with 10 to 20 c.c. of HCl (1:1) each time. Finally take up with dilute HCl, which should give a clear solution, in which the bases may be determined.

Silica in Iron Ores Containing Alumina. Dean (*J. Am. Chem. Soc.*, XXVIII.). The Al_2O_3 contaminating the SiO_2 left by the ordinary evaporating to dryness with HCl, can be rendered soluble in hot HCl by igniting the precipitate for 2 or 3 minutes. If the ignition is too intense or too prolonged the Al_2O_3 becomes again insoluble.

Sulphur in Insoluble Sulphides. De Paepe (*Bull. Soc. Chim. Belge*, XXI., 68). In the case of some sulphides as ZnS, etc., a method called here by the author Klobukow's method, seemed to prove the best. The material is treated with HCl in an atmosphere of H, the escaping H_2S is passed into N/10 I solution in which the excess of I is titrated with $Na_2S_2O_3$. A method suggested by Crismer is mentioned. The sulphide is treated in a flask with N/10 K_2CrO_4 and H_2SO_4. KI then added, and the I liberated by the excess of chromate is titrated with $Na_2S_2O_3$.

Sulphur Determinations Berger (*Bull. Soc. Chim.* [4], I., 194). To completely and quickly oxidize the S of sulphides or even elemental sul-

phur, the author finds that fuming HNO_3 with addition of KBr is quite effective. An amount of material containing 0.1 to 0.2 of S is treated with 10 c.c. fuming HNO_3 and then 0.5 to 1 gm. solid KBr is added. Evaporate to dryness on the water bath, which completes the oxidation. Take up with HCl and evaporate to dryness, repeating this operation three or four times to expel all HNO_3. Dilute, boil, filter, and in the clear filtrate precipitate with $BaCl_2$ as usual.

Hydrocyanic Acid. Weehuizen's test modified. Thiery (*J. Pharm. Chim.*, XXV., 51). A phthalophenone test paper is thus prepared: Filter paper is wetted with a solution containing 1 part $CuSO_4$ in 2,000, and, after drying cut into strips. Immediately before use in the test, it is moistened with a solution of alkaline phthalophenone. To prepare this 0.5 gm. phenolphthalein is dissolved in 30 c.c. absolute alcohol — distilled water is then added until a faint turbidity is produced and then 20 gm. NaOH is added. Al powder is then added little by little until the color is discharged. The solution is then diluted to 150 c.c. with water which has been boiled, and then cooled out of contact with the air. After filtering it is ready for use. The coloration given on this paper by HCy is permanent for 24 hours. One part in two million may be detected. Persulphates, hypochlorites, perchlorates and Na_2O_2 give a coloration which disappears in a few hours. No coloration of the kind is caused by H_2O_2, Fe_2Cl_6, HNO_3 or ethyl nitrate.

Cyanogen Iodide in Iodine. Mulbauer and Hac (*Zts. Anal. Chem.*, XLIV., 286). On triturating a weighed amount of the I with conc. H_2SO_4, the cyanide is converted to ammonia which combines with the H_2SO_4. On adding one volume of water and distilling, the I is driven out, and in the remaining solution the NH_3 can be determined by adding excess of alkali and distilling in the usual manner. Ordinary commercial I was seldom found to contain ICN.

Barium Peroxide — Analysis. Loeb (*Chem. Ztg.*, XXX., 1275). Dissolve 1 gm. in 50 c.c. of $N/2$ HCl. Add 20 c.c. of a 10 per cent. solution of $MnSO_4$ and then titrate with $N/4$ permanganate (1 c.c. = 0.0221 gm. peroxide). The results agree with those obtained by iodometric method which consist in dissolving 0.5 gm. in 50 c.c. H_2O with 5 c.c. HCl (Gr. 1.124) in a stoppered flask. Then add 20 c.c. of 10 per cent. KI and titrate with standard $Na_2S_2O_3$.

In H_2SO_4 solution much BaO_2 is occluded in the $BaSO_4$ rendering titration by permanganate inaccurate.

Adulteration of Red Lead. Frehse (*Ann. Chim. Anal.*, app. XI., 176). Samples of red lead have been found to be adulterated with heavy spar, the color being kept by addition of Orange II. Shaking up with alcohol will dissolve the coal tar color. In several samples the author found 5 to 20 per cent. $BaSO_4$, 10 to 25 per cent. ochre and orange II. to bring up the color.

Lewis Thompson Calorimeter. Salvadori (*Gazetta*, XXXVI., II., 202). With some fuels the combustion is incomplete when using the ordinary mixture (3 parts $KClO_3$ with 1 part KNO_3). The addition of 1 part NH_4NO_3 to this mixture, was found to cause complete combustion, and the results agreed within 5 per cent. with those obtained in the Mahler calorimeter.

ABSTRACTS OF RECENT MINING DECISIONS.*

Liability Involved in Removal of Culm.

A lease of a coal mine provided that the lessor was entitled to a certain sum per ton for coal which the lessee accepted as merchantable, and any culm that the lessee did not accept should be the property of the lessor. Under such a provision it was held that any culm that the lessee refused to accept was the property of the lessor, and that by mingling the culm from the mine leased with that from other mines, and taking unqualified possession, and exercising dominion over the same, and in removing it beyond the power of the lessor to assert ownership, the lessee exercised its option in favor of taking all the material mined as merchantable coal under the lease.

Genet *v.* President, etc., of Delaware, etc. Canal Co., (N. Y.) 79 N. E. 437.

Rights of Joint Owners in Tunnel.

Two persons owned an undivided half interest in a mining claim. One of such owners continued a tunnel driven on the claim through such claim to another mine owned by him, and thereafter worked his mine and attempted to convey the output through such tunnel, basing such right on the fact of his joint ownership of such mine. In a controversy over such right it was held that the owner of an undivided interest in a mining claim had no right to use a tunnel driven on the claim to convey ore from an outside claim.

Laesch *v.* Morton, (Colo.) 87 Pac. 1081.

Two Mine Openings to Surface.

A statute made it the duty of a mine owner to have and maintain at least two available openings to the surface from each seam or stratum of coal work, whenever required by the chief mine inspectors. When the mine owner required two openings, the statute was not satisfied with one opening divided into two parts by a thin wooden partition.

Howells Min. Co. *v.* Gray, (Ala.) 42 So. 448.

Breach of Contract Due to Strikes.

A contract for sale and delivery of coal from a certain mine at stated prices, provided that the delivery should be subject to strikes which might delay or prevent shipment. Under such a provision it was held that the seller was not excused from performance on account of a strike at the mine which did not prevent or delay shipments of coal but

* Prepared for the School of Mines Quarterly by J. W. Thompson, Attorney-at-Law, Indianapolis, Indiana.

merely increased the cost of production and the cost to the seller, and that a refusal to make deliveries for such reason was a breach of the contract.

Cottrell *v.* Smokeless Fuel Co., 148 Fed. 594.

RIGHTS OF LOCATOR AND PURCHASER.

It is said that the locator of a mine, without obtaining a patent, acquires the possessory title thereto against all the world, and as against the government so long as he performs the annual amount of work required thereon; and he may transfer this possessory right or title to a purchaser, who may, as the apparent owner, hold it against unrecorded equitable claims, without notice. The purchaser of the legal title of a locator has a prior and superior equity over a claimant of a prior equitable interest only.

Reed *v.* Munn, 148 Fed. 731.

LIABILITY FOR CONDITION OF MINE TRACKS.

A person employed as a track layer in a coal mine, was charged with the duty of keeping the tracks in repair, but not with the duty of keeping them free from debris at switches, and that he did not, while temporarily acting as driver of a car, assume the risk of injury arising from the failure of the employer to keep the switches so cleared of obstructions as to enable them to work automatically as designed.

Central Coal, etc., Co. *v.* Walker, (Ky.) 99 S. W. 309.

ASSESSMENT WORK.

Where the original locator of a mining claim suspended work for four years, and an adverse location was then made, money expended by the first locator in employing watchmen for the premises, was not a compliance with the statute requiring not less than one hundred dollars worth of work to be performed or improvements made during each year. But where the locator did work in good faith for the purpose of developing the mines, in strict compliance with the statute, a court is not justified in substituting its own judgment as to the wisdom and expediency of the method employed in the development, in place of the owners.

Gear *v.* Ford, (Cal.) 88 Pac. 600.

MISREPRESENTATION. NEGLECT TO RESCIND CONTRACT.

A purchaser of mines took possession and continued working the same. Within four months he learned that material misrepresentations had been made by the vendor as to the value and richness of the mines, but continued to operate the same for development and production for two years, until after suit had been commenced by the vendor to foreclose a mortgage given to secure the purchase money. No notice of an intention to rescind on the ground of fraud had ever been given. The court ruled that such delay and laches amounted to a waiver of the right to rescind, yet the purchaser could plead the resulting damages

because of the fraud, as a failure of consideration as a defense to the action on the note given for the purchase money. But the purchaser, under such circumstances, where he had not fully performed the agreement on his part, could not, with full knowledge of the vitiating fraud, continue performance, voluntarily subject himself to damages, and then recover therefor.

Richardson *v.* Lowe, 149 Fed. 625.

SEVERANCE OF TITLE TO MINERALS.

Coal or other minerals may be severed from the surface of the land, and may run in its own different line of title without reference to the other. A contract regarding coal in place may be a sale absolute, a conditional sale, or a lease.

Gallagher *v.* Hicks, (Pa.) 65 Atl. 623.

TIME WITHIN WHICH CONSTRUCTIVE TRUST MAY BE ENFORCED.

An action to enforce a constructive trust in a mining claim arising out of the fraudulent acts of the co-owner of the plaintiff, was held subject to the limitations, that an action for relief on the ground of fraud or mistake, shall be commenced within two years after accrual of the course of action.

Delmoe *v.* Long, (Mont.) 88 Pac. 778.

RIGHTS OF PURCHASE OF MINERALS IN PLACE.

A sale of the mineral and the severance of the estate carries with it the right to remove or use so much of the containing strata, above and below, as may be reasonably required for the proper mining of the mineral. And where there are no restrictions in the grant, the space which may be left by the removal of the mineral and by the removal of so much of the containing strata as may be reasonably required for the operation of mining, remains a part of the property of the mine owner until the exhaustion of the mine, and may be used by him during the continuance of the estate as he may see fit, on condition that such user does no injury to the surface. This right to use the exhausted part of the mine includes the right to haul mineral and drain water through such space from other mines.

Moore *v.* Indian Camp Coal Co., (Ohio) 80 N. E. 6, (February, 1907).

NECESSITY OF ACTUAL DISCOVERY ON PLACER GROUND.

While in some instances courts have questioned the necessity of an actual discovery of mineral upon gold placer grounds, it is now the established rule that appropriate discovery is as necessary to the location of a placer claim as to the location of a lode claim.

Steele *v.* Tanana Mines R. Co., 148 Fed. 678.

DETERMINATION OF MINERAL LAND.

A showing that colors of gold in each instance of panning, and that many of the pans showed what miners and prospectors are in the habit

of calling "good prospects" of gold, and pans containing colors readily and easily seen, and in some instances quite a number of them, was held not sufficient to justify a person of ordinary prudence in further expending labor and means with a reasonable prospect of success. Such prospects were insufficient to show that the land was so valuable for mineral as to take it out of the category of agricultural lands, and to establish its character as mineral land, in a contest between a mineral claimant and another claiming the lands under other laws of the United States.

Steele *v.* Tanana Mines R. Co., 148 Fed. 678.

What Constitutes Valid Discovery.

The rule as to the sufficiency of a discovery of a placer claim was stated by a Federal Court thus: "There must be some gold found within the limits of the land located as a placer gold claim, but it cannot be said in advance as a matter of law how much must be found in order to warrant the court or jury in finding that there was in fact a discovery such as the law requires. The question must be decided, not only with reference to the gold actually found within the limits of the claim located, but also in view of its situation with reference to other lands known to contain valuable deposits of placer gold, and whether its rock and soil formation are such as is usually found where these deposits exist in paying quantities, and, further, in considering the evidence bearing upon the general question it must not be forgotten that the object of the law in requiring the discovery to precede the location is to insure good faith upon the part of the mineral locator, and to prevent frauds upon the government by persons attempting to acquire patents to lands not mineral in its character."

Lange *v.* Robinson, 148 Fed. 799.

Fraudulent Relocation of Claim by Lessee.

A lessee of a mining claim who has contracted to do an amount of work thereon which would be a sufficient compliance with the legal requirements in respect of development, and also to notify the lessor of any intention to surrender or abandon the lease, cannot upon failing to perform his obligations secretly relocate the claim, and so secure and hold the title for himself. A patent obtained under such circumstances was decreed to be held in trust for the lessor.

Stewart *v.* Westlake, 148 Fed. 349.

Abandonment of Claim.

A mining claim may be said to be abandoned when the locator leaves it without any intention of returning, and without regard as to what becomes of the claim or who may appropriate it. But the mere leaving of a claim with intent to return later is not an abandonment.

Davis *v.* Dennis, (Wash.) 85 Pac. 1079.

PROOF REQUIRED OF ABANDONMENT OR FORFEITURE OF LOCATION.

Where a person makes a valid mining location, he need not keep actual possession of the claim, but his right of possession will continue until he, in fact, abandons or forfeits it by failure to do the work required by law. The burden of proving a forfeiture or abandonment in such case is upon the party asserting it. Such a forfeiture can only be established by clear and convincing proof of the locator's failure to perform the labor required by the statute, and the burden rests upon the party asserting such failure, and this is a question of fact.

Gear *v.* Ford, (Cal.) 88 Pac. 600.

MINERS' RESPONSIBILITY FOR ACCIDENTS.

A miner was engaged in turning a room off from the main slope of a mine; he had mined the coal from some distance from the slope; had prepared shots and directed that these shots be exploded by the shot firer in order to loosen the coal in such room and to mine the same therefrom; that the rock over the room and the slope, in which the miner was working, was loosened and broken by the shots; that it was the part of the miner's duty, before beginning the mining down of the coal to examine for and determine the result of the shots, and that without examining the roof to determine the result of such shots, he began to mine down the coal and was injured by falling rock. Under these circumstances it was held by the court that the portion of the slope occupied by him was his working place in the sense that he was required to keep it safe from falling rock, loosened by his own efforts in turning the room, and that the owner of the mine was not liable for the injury.

Rolla *v.* McAllester Coal Min. Co., (Ind. Terr.) 98 S. W. 141.

WARNING TO EMPLOYES.

The duty of a mine owner operating a mine to warn employes of an expected explosion in blasting, is the duty which cannot be delegated to a fellow-servant of the operator and the owner of the mine thereby escape liability.

Hendrickson *v.* United States Gypsum Co., (Iowa) 110 N. W. 322.

RIGHT TO DRAW OIL FROM ADJOINING LAND.

A land owner may drill an oil well any place on his own land, though this may draw from an oil well on adjoining lands. The only remedy of the adjoining land owner is to drill a well on his own land. But where the same person holds oil leases of two adjoining farms he will not be permitted to combine with one land owner to drain the oil from the well on his land to the detriment of the other land owners.

Barnard *v.* Monongahela Nat. Gas Co., (Pa.) 65 Atl. 801. (January, 1907.)

RIGHTS OF LOCATORS: INCOMPLETE LOCATION.

The locators of a mine, on the day of the location, posted notices thereof, set stakes at the northeast and southwest corners of the claim and

remained thereon until twelve o'clock midnight of the same day and immediately left the claim and never did anything further in the way of taking possession thereof. Three months thereafter another person made a new location of such claim. Under these facts it was held that the first locators did not proceed far enough to acquire rights sufficient to make the claim abandoned property within the meaning of the statute, and that the relocation was sufficient, though the certificate did not state that the whole or any part of the new location was located on abandoned property, where it further appeared that the relocators complied with the requirements of the statute by sinking a discovery shaft upon the lode.

Paragon Min. etc. Co. *v.* Stevens Co. etc. Co., (Wash.) 87 Pac. 1068.

Proper Contents of Location Certificate.

A statute provided that a certificate of a mining location should contain a description of the claim by such designation of natural or fixed objects as should identify the claim. Under this statute a certificate was held prima facie sufficient which described the location in a designated mining district and county and further described the claim as lying west of other designated claims. The failure to give distances and directions did not affect its validity. It was further held that the failure to recover the certificate within sixty days did not render it invalid; the effect of such failure being that it might affect intervening rights.

Slothower *v.* Hunter, (Wyo.) 88 Pac. 36.

Description of Placer Location.

The United States statute requiring the notice of the location of a claim to contain a description by reference to some natural object or permanent monument as would identify the claim, was held to be sufficiently complied with under a system of locating placer mining claims upon a gulch or creek, and calling the first "Discovery Claim," and then numbering the others from this first claim up or down the gulch or stream, and giving to the side or bench claims the same number as those upon the creek, with the addition of a letter of the alphabet. And that a recorded notice of the location of a claim in such locality, describing it as "13A. Below 'Discovery' on Cleary Creek," was held sufficient.

Smith *v.* Cascaden, 148 Fed. 792.

Sufficient Description of Claim.

The statute requires that records of mining claims shall contain such a description of the claim by reference to a natural object or permanent monument as will identify it, and that a location certificate shall contain such a description as shall identify it with reasonable certainty. Under these requirements a description as beginning at a certain stated corner, declaring a parallelogram by courses and distances, and concluded thus: "Corner No. 1 of Wichita Lode joining corner No. 4 of Wichita Eagle Lode." This was held to be a sufficient reference to a permanent monument as would render the certificate prima facie competent as evidence of the location. It was also held that a reference to a natural

object or permanent monument in such certificate was not conclusive that the law has been complied with, requiring such a reference to natural objects or permanent monuments as will identify the claim; that evidence was admissible that a person could not take the description therein, and, by referring to the natural object or permanent monument therein mentioned find the premises claimed.

Londonderry Min. Co. *v.* United Gold Mines Co., (Colo.) 88 Pac. 445.

PARALLELISM OF END-LINES.

The requirement of parallelism of end lines of lode mining locations by the Act of 1872, cannot be deemed to apply where the location had been made at the time of the passage of that Act, and the proceedings under the Act of 1866, had then so far advanced as to exclude adverse claimants, in view of the various provisions of the latter Act for the protection of all rights previously acquired under existing laws, and of the provision that prior locators shall have "the exclusive right of possession and enjoyment of all the surface included within the lines of their locations, and of all veins, lodes, and ledges throughout their entire depth, the top or apex of which lies inside of such surface lines extended downward vertically, although such veins, lodes, or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical side lines of said surface locations."

East Central, etc., Min. Co. *v.* Central, etc., Min. Co., 27 Sup. Ct. 258.

METALLURGICAL ABSTRACTS.

BY WILLIAM CAMPBELL.

ANTIMONY.

The Antimony Industry: F. T. Havard, *E. and M. J.*, 82, 1014. Mines of France and Italy are largest producers. Largest works the Société Anonyme Franco-Italienne. Great demand for oxides, sulphides, etc., as paints. Metal used for bearing metal manufacture. Increased demand for hard lead and rise in price of antimony follows. Classes of ore: (1) Auriferous, 40–70 per cent. Sb. (2) Ditto, less than 40 per cent. Sb. (3) Sulphide and oxide free from precious metals 40–70 per cent. Sb. (4) Under 40 per cent. Sb. (5) Mixed Cu, Sb, Zn ores. (6) Lead ores 40–60 per cent. Pb, 3–10 per cent. Sb. Processes of extraction: (1) Liquation. (2) Crucible. (3) Open-hearth. (4) English method — preheated change of Sb ore dropped into a fused bath of iron sulphide and iron. (5) French process — volatilization of antimony as oxide and reduction of oxide in a reverberatory.

The Modifications of Antimony: Stock and Siebert. *Bull. de la Soc. Chim.*, 1906, 583. Describes the formation of yellow and black varieties and some of their properties.

COPPER.

Arizona and Sonora: D. E. Woodbridge. *E. and M. J.*, 81, 896, 990, 1134, 1180, 1229; 82, 8, 50, 103, 150, 242. Most important copper districts of Arizona are: At and near Bisbee, at Jerome, at Clifton-Morenci and at Globe. The paper deals first with the present expansion, then takes up the different camps. The Old Dominion is the only smelter in the Globe District; concentrating mill 500 tons per diem; blast furnace and converting plant for 1,600 tons raw ore per diem. Four blast furnaces, three of 42 × 180 and one 50 × 196 in., charge 7 ft. Three have brick shafts, No. 4 has water jackets all the way up. Furnaces are all fed from a large wooden storage bin system, holding 2,500 tons ore, 700 tons coke, lime and concentrates. Ores treated include coarse crushed firsts and Old Dominion concentrates from Nacozari and Cananea, Mexico. Matte assays 50 per cent. Cu: slag 38 per cent. SiO_2, 8 per cent. Al_2O_3, 11 per cent. CaO. Converter slag goes to settlers. Briquettes made from flue dust with concentrator slimes (1.5 per cent. Cu) using up to 10 per cent. An old black-copper slag dump of 400,000 tons, 4 per cent. Cu, is being run through; is delivered at 40c. per ton. At Clifton are the smelter, leaching works, etc., of the Arizona Copper Co., the smelter and mill of the Shannon Co. At Morenci, mines, concentrator and smelting works of Detroit Copper Co. and mines and some concentrators of the Arizona Company. At Metcalf, the mines of the Shannon and the Arizona.

The Detroit company's smelter has one large furnace, 264 × 48 in., 14 ft., 10 in. to charging floor, feed of 7 ft. Takes 400 tons daily. Other smaller furnaces. 40 ft. × 9 ft., reverberatory for experimenting with flue dust and slag. Takes slag from settler and reduces Cu content from 0.48 to 0.32 per cent. Cu. It answers its purpose in settling the flue dust and fines question. About 350 tons slag and about 60 tons flue dust daily. Matte is tapped from the furnaces, through launders into converters on lower level. A 400,000 ton dump of slag 4–6 per cent. Cu is being worked over.

The Shannon Smelter consists of two 42 × 180 in. furnaces and one Power and Mining converter. Matte averages 60 per cent. The Arizona Copper Company smelter is badly arranged. Six furnaces, slag 0.35 per cent. Cu. Acid plant to leach low grade oxide ores. Matte 55 per cent. Cu is converted.

The Copper Queen Smelter. On account of the diversity of the ores smelted, there are four bedding pits, each 800 × 40 × 11 ft., holding a total of 70,000 tons. Mechanical spreader or plough. Charge loaded into cars by Thew steam shovels. Five 18 ft. furnaces, and three 20 ft., two more being added. Height of column of charge 10–11 ft., 40 tuyeres, 4 in. dia. The 10 furnaces are in line 15 ft. apart. One settler to each pair. Settlers 10 ft. × 23 ft. 18 ton slag cars. 7 converter stands, one more building. Barrel type. 36 shells. 10½ ft. long × 8 ft. dia. 8 Sterling boilers of 500 h. p. Oil fired. Elevation and section of Copper Queen blast furnace shown on p. 298–299.

La Cananea Mining Camp. D. E. Woodbridge. *E. and M. J.*, 82, 623. Belt conveyor system at the furnaces of Cananea Copper Co. 2 classes of furnaces. Old style Mitchell hot blast, side feed; being replaced by modern mechanical feed. 8 blast furnaces in use. 4 McDougall roasters, 6 shelf, 50 ton, 18 ft. dia. being installed. A large new reverberatory 100 × 19 ft. (with 3 Sterlings of 300 h. p.) handles all flue dust. New blast furnaces 58 × 180, cold blast. Paper describes the mill, etc.

The Mount Lyell Mining and Railway Co. 1905. R. Sticht: *Metallurgie*, III., 686, 709, 760. This is part of a series of articles on the work of the company. In this part the smelter work is mentioned and photos of the plant and furnaces are shown.

Notes and Comments on the Pyritic Process of Mount Lyell, Tasmania: R. Nicholls. *J. Chem. Met. and M. Soc. S. A.*, VII., 135. Deals with the methods old and new. Slag SiO_2 38.5. FeO 46.3, Al_2O_3 7.5, CaO 5.9. Chemistry of process. Chemical laboratory and methods used.

The Washoe Plant of the Anaconda Copper-Mining Co. in 1905: E. S. Austin: *Bull. A. I. M. E.*, 1906, 529. Gives plan of plant, sampling, concentration, blast furnace plant 7 furnaces 56 × 180 in. A new furnace made by joining furnaces Nos. 1 and 2 and including the 21 ft. space between them, giving a furnace 51 ft. long by 56 in. wide. Similarly Nos. 3 and 4 and Nos. 5 and 6 were united. Charge sheet given. Briquetting plant, roasting plant, 56 Evans-Klepetko-Mc-

Dougall roasters, 7 reverberatory furnaces each with two 300 horse-power Sterling boilers. 19 ft. × 110 ft. Converter plant of 10 stands. Arsenic plant.

The Tacoma Copper Refinery: D. A. Willey. *E. and M. J.*, 82, 147. Bennett's slag-casting machine of 144 tilting moulds, capacity 20 tons. Slag brought to it from furnace by crane and ladle. Reverberatory furnace for concentrates. Matte 45–55 per cent. Cu to ladles to two converters. The furnace for casting anodes is of the rotary type, fuel oil. Anodes of 125 lbs. Output of works is 30–43 tons daily. Electric power by long distance transmission from Electron, Wash. Originally the Tacoma works erected for the reduction of lead ores, for which they have a capacity of about 300 tons daily, the output of metal being about 1,000 tons a month.

Matte Converting: H. W. Hixon: *E. and M. J.*, 82, 197. Gives some historical notes. In treating copper nickel matte the converting is stopped at 1 per cent. Fe, for beyond that nickel is oxidized and remains so, and so all Sudbury ores can only be converted to high grade mattes. Mattes run 80 per cent. CuNi, 18 per cent. S, 1 per cent. Fe, 1 per cent. oxygen. Converters lined in various ways, according to locality, siliceous silver, gold or copper ores being used for lining material.

Copper Converter Melting its Own Matte: E. Jacobs. *E. and M. J.*, 82, 440. At British Columbia Copper Co. smelting works at Greenwood, B. C., under emergency, in rebuilding, some matte had to be converted, a wood fire lighted in converter shell, then 1,500 lbs. coke dumped in, light blast, when fuel was red hot 5 tons cold matte placed on top, full air pressure turned on, as matte melted more cold added. This was repeated till enough added, then blow was finished. About 15 tons of 40–50 per cent. matte converted in 3½ hours.

The Cost of Smelting Copper Ore: G. F. Beardsley. *E. and M. J.*, 82, 397. Information for investors and others interested in costs. Mt. Lyell, 1903. Labor, $5.44 per 24 hrs. Coke, $12.50 per ton. Cost of treatment, short ton, $4.8638. Tennessee, 1905. Labor, $2.60 per 24 hrs. Coke, $3.50 to $6.00 per ton. Cost of treatment, short ton, $3.0384. Mexico, 1906. Labor, $1.50 gold per 24 hrs. Coke, $30.00 per ton. Treatment, $4.66. Freight on blister to N. Y., $30.00 gold per ton.

The Metallurgy of Copper in Chile: A. Gmehling. *Oester. Zeit.*, Feb. 10 and 18, 1906. Abs. *E. and M. J.*, 82, 456. Process used at Guayacan, Chili, includes roasting of copper matte, production of H_2SO_4 and extraction of copper from low grade ores by this acid. Pure matte purchased from smelters. Cu 40–50 per cent., S 22–27 per cent., Fe 23–30 per cent., Ag. 150 gms. per metric ton, Au 5 gms. Crushed and roasted in Rhenania muffle furnaces. Each muffle holds 3,000 kg. matte. Total capacity of a furnace is 36 metric tons. Matte roasts in 36 hrs. During 24 hrs. a block roasts 12,000 kg. matte, using 250–300 kg. coal. 30,000 cu.m. of gas per 24 hrs. S = 2–4 per cent. in roasted matte. Roasted matte is returned to smelters and run with siliceous ore to blister. Part of the copper running 80 per cent.

is roast-smelted in reverberatory for "Chilean Standard Ingots," 99.95 pure.

Slag Granulating and Conveying Device: H. W. Hixon. *E. and M. J.*, 82, 553. Method used at Mond Nickel Co.'s works, using water under 20 ft. head.

Electrolytic Precipitation of Bronzes: B. E. Curry, *J. Phys. Chem.*, X., 515. The best plating solution for bronzes should contain about 5 grams of free oxalic acid and 55 grams of ammonium oxalate per 1000 c.c. water. The presence of chloride is preferable to large amounts of sulphates. Difficult to precipitate a good bronze with less than 75 per cent. Cu.

The Blake-Dennison Weighing Machine: E. and M. J., 82, 158. Description and illustration of these automatic weighers for belt conveyors, which will certainly be in vogue at large smelters.

Fuels, Refractories, Furnaces.

Coke Oven Construction: W. M. Judd. *E. and M. J.*, 82, 877. Describes the Beehive oven, its construction, method of running and products.

Beehive Oven Construction: H. N. Eavenson. *Mines and Minerals*, 27, 81. A paper giving plans and details of work in Connellsville and Pocahontas districts. Also in Iron and Coal Tr. Rev. LXXIII., 1172.

Gaseous Fuels: O. Nagel. *Elect. and Met. Ind.*, IV., 403. Deals with natural gas, illuminating gas, producer, water gas, semi-water gas. Many valuable tables given of ideal producer gas.

Mixed Distillation and Combustion Gases: O. Nagel. *Elect. ana Met. Ind.*, IV., 480. Gives tables of composition, etc., of generator gases from wood, peat, bituminous coal, lignite.

The Hughes Gas Producer. E. and M. J., 82, 1061. Gives section showing working of producer made by Wellman-Seaver-Morgan Co.

Composite Metallurgical Vessels: A. L. Queneau. *E. and M. J.*, 82, 678. Method of making composite retorts in Dor press, so that they have a refractory lining and shell.

Electric Furnace for Heating Crucibles: O. P. Watts. *Elect. and Met. Ind.*, IV., 275. Describes a resistance furnace for use with a number of crucibles at one time. Used to melt electro-iron.

Vertical Arc Furnaces for the Laboratory: S. A. Tucker. *Electro. and Met. Ind.*, IV., 263. Shows a vertical arc or pot furnace of Achesan graphite. Drawing dimensioned.

Gold and Silver.

A Metallurgical Revolution in Guanajuata: J. W. Richards. *Electro. and Met. Ind.*, IV., 345. A well illustrated article on the Patio Process, which is now being displaced by modern methods.

Other Metallurgical Methods at Pachuca: T. A. Rickard. *M. and Sci. Press.*, 93, 691. The Kroeneke process at the Hacienda la Union.

Sturtevant roll-crusher. Abbé tube mill for undersize and rolls for oversize. It is intended to replace barrel amalgamation by cyanide.

A New Cyanide Plant: Mark R. Lamb. *M. and Sci. Press.*, 93, 780. Describes a plant to treat 140 tons $60 ore crushing to 150 mesh. Concentrate 5 per cent. Free gold 5 per cent. as follows: Gyrating crusher, 40 stamps 1,600 pounds each, Dorr classifier, Vanners, Dewatering cone, 3 tube mills 4′ x 12′, cones or Dorr classifier, slimes to 6 ft. thickening cone-canvas plant, settlers, agitators, slime storage, Butter's filter and Merrill's zinc dust precipitation press.

Cyanide Practice at the Liberty Bell Mill, Telluride, Colo.: W. E. Tracy. *E. and M. J.*, 82, 149. The process is coarse crushing by stamps in weak KCN solution; amalgamation; regrinding sand in tube mills; second set of amalgamation plates; treating combined slimes and reground sand by agitation; Moore filter; solution through zinc boxes back to battery storage tank. 80 stamps 850 lbs. Solution 1 lb. per ton. 4 parts sol. to 1 part ore. 14 mesh. Pulp classified by two Dorr scraping sizers. Three Abbé tire-type tube mills. Agitators 17 ft. dia. 11 ft. to top of the 45° cone. Hold 35 tons dry ore per charge. Pulp 2 pts. solution to 1 of ore. Solution strength raised to 1.5 lb. per ton. 12 hrs. agitation. 12 five compartment zinc boxes. Strong sol. = 1.3 lb.: weak = 0.8 lb.

Ore Treatment at the Combination Mine, Goldfield Nevada: F. L. Bosqui. *M. and Sci. Press*, 93, 413 and 451. Ore divided into oxidized and sulphide. The first goes through 10 stamps over 2 plates, Bryan mill, 2 Frue and 2 Triumph vanners, classifiers. 4 settlers and 4 leaching vats for sand. Slimes to agitation. Sulphide ore after battery and one Wilfley to Bryan mill and 3 Frue vanners. Tube mill 3 Wilfley slimers. Slime to classifiers of oxidized ore.

Cyanide Practice at El Oro: T. A. Richard. *M. and Sci. Press*, 93, 381, 416. New mill of 100 stamps and up-to-date cyanide equipment has: (1) Mechanical handling of ore. (2) Heavier stamps. (3) Regrinding in tube mills. (4) Mechanical agitation of slime by stirrers and centrifugal pumps.

Recent Innovations in Rand Metallurgical Practice: G. A. and H. S. Denny. *E. and M. J.*, 82, 1217. New Plant of Meyer and Charlton Gold Mining Co. shown in plan, and solution and pulp flow diagrams given. Stamp battery, Amalgamated plates, Spitzluten, 2 tube mills, shaking amalgamated tables — Spitzkasten, percolating plant, precipitation. Slime settlers and storage, filter presses, precipitation.

Rand Metallurgical Practice and Recent Innovations: G. A. and H. S. Denny. *S. A. Assoc. of Engs.*, 1906. Abs. *J. Chem. Met. and M. Soc. S. A.*, VII., 98. Any subsequent equipment should omit: (1) Slimes plant. (2) Sand treatment plant. Therefore we need only (*a*) crushing and fine grinding in cyanide solution, (*b*) scheme for separation of solutions from fine ore particles. 6 tons circulating cyanide solutions to 1 ton of ore milled. Give an ideal plant for all sliming work at Meyer and Charlton.

Great Boulder Proprietary Gold Mine: R. Allen. *Mining Journal, London*, May 25, June 30, 1906. Kalgoorlie, E. Coolgardie Goldfield, W. A. Coarse grinding. Dry. 2 large Krupp ball mills, 12 Griffin Mills. Roast 12 Edwards and 8 Merton Furnaces. KCN solution. 3 solu. to one of ore. 12 Wheeler pans overflow to 10 more pans. Spitzkasten. Sludge agitation treatment. Filter pressed in 4 Dehne and 9 Martin Presses. Total cost $2.80.

Methods of Gold Extraction in Western Australia: C. Göpner. *Metallurgie*, III., 457, 613, 656. Deals with articles by Robert Allen and H. T. Brett in the Monthly Journal of the Chamber of Mines of Western Australia. (1) Oroya-Brownhill. (2) Associated Northern Gold Mine. (3) Sons of Gwalia Mine. (4) Ivanhoe.

Cyanide Practice at Kalgoorlie: H. T. Brett. *M. and Sci. Press*, 93, 744. A letter replying to James' criticisms on tests at Ivanhoe Mine:—

Crushing and Grinding at Kalgoorlie: A. James. *M. and Sci. Press*, 93, 109. Deals with the subject of pans at Kalgoorlie, Diehl bromo-cyanide process brought tube mill. Criticizes tests published by Ivanhoe Company on pans v. tube mills.

Tube-Mill Practice: W. R. Dowling. *J. Chem. Met. and M. Soc. S. A.*, VI., 309. Work on the Robinson Deep. Plant 200 stamps through 700 mesh. (1) Eleven classifiers, launder to 2 dewatering spitzkasten; (2) two tube mills 22 × 5 ft. launders to (3) for one tube mill 4 shaking amalgamated tables 12 × 4½ ft., for the other 8 small ones 6 × 4½ ft. launders with mercury traps—convey pulp back to tailings elevators. The different sections are treated in detail.

Tube Mill Lining: M. and Sci. P., 93, 108. Describes lining used at Waihi mine, N. Z.: H. P. Barry's patent. Lining of rough stone.

Cyanide Practice with the Moore Filter Press: R. G. Brown. *M. and Sci. Press*, 93, 261, 262. Standard mine, Bodie, Calif. Moore process was tested in 1903, and in 1905 was running regularly. Weak cyanide solution used in 20 stamp battery. Vanners. Four trenier sand-pumps to elevate flume to slime plant. Allis-Chalmer tube mill for re-grinding. Good illustrations given of Moore filters, and method of working.

Notes on Improvements in Cyanide Treatment of Sands and Slimes: C. H. Pead. *J. Chem. Met. and M. Soc. S. A.*, VI., 76. Advocates adding free cyanide to every compartment of zinc box, to obtain longer run without changing. Addition of carbonate to cyanide solutions aids precipitation. Sulphuric acid additions to working solutions often has beneficial effect.

Proposed Method of Treating Sand Dumps: Truscott and Yates. *J. Chem., Met. and M. Soc. S. A.*, VI., 213. Propose to break down dump by hydraulicking, through launder with rough surface to catch amalgam and free gold. Spitzlutte separation of coarse sand and pyrite which will carry the values. Flint mills to grind to slimes or fine sands.

A Quick Treatment of Cyanide of "Black Sands": D. V. Burnett. *J. Chem. Met. and M. Soc. S. A.*, VI., 240. A small 5 ft. round vat

and paddle used. Charge 1,144 lbs. running about 44 oz. Treatment in lime wash, 0.3 per cent. KCN sol. decanted off (10 oz.) 0.3 per cent. sol. decanted off (about 3 oz.) and so on. Period of treatment 6 days, extraction of 99.14 per cent.

Notes on the Use of the Filter Press for Clarifying Solutions: Truscott and Yates. *J. Chem. Met. and M. Soc. S. A.*, VII., 45. Describes the treatment at the Redgang mine in Sumatra. Two small Johnson presses used after settling tank makes solution quite clear.

Proposed Process for Treatment of Zinc Gold Slimes before Smelting: Meyer. *J. Chem. Met. and M. Soc. S. A.*, VI., 361. Gold slimes dried and oxidized. A saturated sol. of ammonium carbonate added 10 to 1 of slime. Zn, Ag and Cu in filtrate from press. Filtrate distilled with limestone in large boiler, ammonium carbonate distills leaving a matte of silver, copper and zinc. The ammonium carbonate collected in solution.

Electrolytic Precipitation of Gold from Cyanide Solutions: B. Neumann. *Elec. and Met. Ind.*, IV., 297. Experiments made to determine ampere-hour efficiency in electrolysis of dilute cyanide solutions when the current density or concentration or length of run are changed.

The Belt Conveyor in Cyanide Plants: E. and M. J., 82, 922. Plant built jointly by Knights Deep and the Simmer and Jack on the Rand uses Jeffrey belt. 40 leach tanks, 40 x 9 feet in 4 rows, above are 16 like collecting tanks placed concentric with the leaching tanks 4, 5, 6 and 7 of each row.

Treatment of Silver-Lead Tailings by the Cyanide Process: E. J. Sweetland. *E. and M. J.*, 82, 342. Winters Mine, Douglas Co., Nevada, ships high grade carbonate and bunches of galena to smelters. Low grade is concentrated on New Standard machines. Tailings treated by cyanide. Four 17 x 4 ft. leaching vats, 2 collecting tanks, zinc boxes — 16, circular sheet iron 16 in. diameter, 18 in. high. Tailings run 1¼ per cent. Pb, 0.11 per cent. Cu, $0.41 Au, 7.6 oz. Ag as chloride. The tests on the ore are given at length; then the mode of working.

The New Denver Mint: Whitehead and Healy. *Mines and Minerals*, 27, 1 and 54. An illustrated account of the equipment and work of the mint. The refinery equipped with two electrolytic processes for refining (1) Wohlwill process for gold with 5 per cent. Ag. Electrolyte is trichloride of gold with 5 to 10 per cent. free HCl. 60 gms. metallic gold per litre. (2) Silver cells for parting low grade gold 50–200 base metal. 2 per cent. free nitric acid and 3 per cent. Ag as nitrate is the electrolyte.

IRON AND STEEL.

Notes of Travel in the United States. Rolling of Billets, and Merchant bars: F. Corvee. *Revue de Mét.*, III., 83. Describes the old installation at Duquesne for rolling small billets, the new continuous mill at Duquesne, the mill at Vandergrift, the new installation for merchant bars at Duquesne; illustrated by three plans.

The Metallurgical Situation in France: Saladin and Charpy. *Revue de Mét.*, III., 382. Deals first with the distribution of works in France and their evolution. Production of iron and steel. Technical progress. Material and general method of work. Use of iron and steel. Gives three tables showing strength and use of iron, Bessemer and Siemens-Martin steels.

The Northern Iron Company's Blast Furnace: J. H. Granbery. *E. and M. J.*, 82, 98. The Port Henry plant handles Mineville ores almost exclusively. 5,000 tons basic pig per month. One blast furnace, 69 ft., with 17 ft. bosh, 11½ ft. stock line and 10 ft. hearth; three new stoves 81 ft. x 16 ft. diameter, one old stove 45 ft. x 22 ft. diameter. Coke 1,965 lbs., anthracite 409 lbs., 1,120 lbs. flux per ton of iron, on a year's run. Half page photograph and drawings illustrate the plant.

The Colorado Fuel and Iron Co.: L. Lewis. *E. and M. J.*, 82, 1201. Gives plan of works and describes the 40-inch Blooming mill, Rod mill (double Garrett) and wire mill. Mentions 9, 12 and 20 inch mills for merchant iron, spike, bolt and nut factories, iron, steel and brass foundries; cast-iron pipe foundry, etc. Output, 4 blast furnaces 2,000 tons, Bessemer 2,000 tons. O. H. steel 1,500 tons, rail mill 1,500 tons, 40 in. mill 1,200–2,000 tons daily.

Technical Progress in Blast Furnaces: Simmersbach. *Stahl una Eisen*, XXVI., 262, 319, 389, 463. A long and well illustrated article on recent improvements in blast furnace construction and work.

The Heat Balance Sheet of the Blast Furnace: J. W. Richards. *Elect. and Met. Ind.*, IV , 259, 303. Part of the series of articles on Metallurgical Calculations, works out first the heat received and developed, then that absorbed and disbursed. This is followed by a problem.

The Kiellin Electric Steel Furnace: E. C. Ibbotson. *J. I. and Steel Inst.*, 1906, III., 397. At Gysinge, Sweden, a fixed furnace yielding 1 ton steel a tap, produced 950 tons tool and special steel ingots during the year ending May 31, '06. Charge 80 per cent. Swedish white pig and 20 per cent. steel scrap. Time 7⅛ hrs.; consumed 1128 kilowatt hrs. per ton when adding briquettes to regulate carbon. Time 5½ hrs.: 886 kilowatt hrs. without briquettes. Diagram of a tilting furnace, recently erected, is given.

Electric Smelting of Iron: Elec. and Met. Ind., IV., 265. Abstract of Haanel's report on the experiments made at Sault Ste Marie, Ont., on electric smelting of Canadian iron ores. Furnace shown.

The Nodulizing and Desulphurization of fine Iron Ores and Pyrites Cinder: A. L. Colby. *J. I. and Steel Inst.*, 1906, III., 358. Describes plants at Newark, N. J., of the National Metallurgic Co., at Steelton, Pa., by the Pennsylvania Steel Co., at Hazard, Pa., by the N. J. Zinc Co., at Oxford, Pa., by Empire Steel and Iron Co. The plants consist of a rotary kiln producing 75–90 tons per day, into which is fed a stream of fine ferruginous material, mixed with a binder such as tar, pitch, etc. With increase of temperature the tar combines with the sulphur and both are volatilized. At the hottest end of the kiln

incipient fusion takes place and nodules are produced. A bibliography of 56 titles is given.

The Manufacture of Tool Steel: E. T. Clarage. *Indust. World*, 40, 784. Deals with the manufacture of crucible and gives the effects of various added elements on the properties of steel.

The Art of Cutting Metals: W. L. Taylor. *T. A. I. Mech. Engrs.*, 1906, 1–200. Presidential address, giving an exhaustive discussion of the subject of tool steels and their work.

Tempering and Cutting Tests of High Speed Steels: H. C. H. Carpenter. *J. I. S. I.*, 1906, III., 377. A continuation of research, *J. I. and S. Inst.*, 1905, I., 433. Four chromium-molybdenum and five chromium tungsten steels used, to ascertain whether the temperature at which high-speed steels soften can be pushed higher than 700° C. Sections ⅛ in. thick heated to 1,200° C. and cooled in air-blast. These specimens were then tempered by heating for one hour at a specified temperature 500–800° C. Cutting tests were made. The research resulted in a negative answer.

Nickel-Chrome Steels: L. Guillet. *Revue de Mét.*, III., 462. Four series of steels were made. In the first with 0.2 per cent. C 3, 10, and 20 per cent. Cr is successively alloyed with 5, 12 and 30 per cent. Ni steel. In the second series with about 0.8 per cent. C the same series was repeated. In the third series with about 0.2 per cent. C the Ni was kept around 2.5 per cent. and the Cr runs from 0.5 to 5 per cent. In the fourth series with carbon about .2 per cent. and Ni about 6 per cent. the Cr varies from 0.5 to 5½ per cent. The microstructure and mechanical properties are worked out for the normal steels, quenched, annealed, cemented, etc. The normal steels are divided into five classes. Pearlitic, martensitic, martensitic with carbide, those of gamma iron, those of gamma iron with carbide. Only the pearlitic and the gamma iron steels are industrially important. They are much harder than nickel steels after quenching.

Nickel-Silicon Steels: L. Guillet. *Rev. de Met.*, III., 558. These steels fall into seven classes. Pearlite, pearlite with graphite, all carbon as graphite, martensite, martensite with graphite, gamma iron: gamma iron with graphite. Silicon retards the formation of martensite whilst nickel opposes the precipitation of graphite. Long annealing at 900° C. does not change the state of the carbon. The addition of silicon above 2 per cent. to nickel steels is bad; makes steel brittle under shock.

Quaternary Steels: L. Guillet. *J. I. and S. I.*, 1906, II., 1. The paper gives (I.) a summary of the author's earlier researches on ternary steels, nickel, manganese, chromium, tungsten, molybdenum, vanadium, silicon, aluminium, cobalt, titanium, tin. Part II. deals with nickel-manganese steels; III., nickel-chromium steels; IV., nickel-tungsten steels; V., nickel-molybdenum steels; VI., nickel-vanadium steel; VII., nickel-silicon steels; VIII., nickel-aluminium steels; IX., manganese-chromium steels; X., manganese-silicon steels; XI., chrome-tungsten steels. The author, in conclusion, advises the manufacturer to reject any steel possessing a structure containing either graphite or martensite.

Steels containing pearlite and carbide or sorbite and carbide are good as tool steels. Steels containing gamma iron can only be obtained by the use of high percentages of Ni or Mn or both, in order to avoid the production of steels easily transformed by quenching, annealing, cooling, etc. Are costly and hard to machine. The only structure sought for general purposes is pearlite, and the steels should not contain high percentages of carbon.

The Influence of Nickel and Carbon on Iron: G. B. Waterhouse. *Elect. and Met. Ind.*, IV., 451, 482. A series of 10 bars, Ni = 3.8 per cent., C = 0.4–1.83 per cent., were subjected to heat treatment, A to 1000° C. and cooled in air, B to 880° for 3 hours and slowly cooled. Tables of physical properties are given. Part II. deals with the microstructure. Nickel raises tenacity without lowering ductility. Annealing lowers tenacity without raising ductility. Nickel lowers the transformation points 20° C. for every 1 per cent. Ni.

The Influence of Vanadium on Iron and Steel: P. Pütz. *Metallurgie*, III., 635, 649, 677. A series of 50 steels were made. A large number of cooling curves taken. Most show the pearlite critical point between 700 and 710° C. Their physical properties were tested. *Metallurgie*, III., 714. The microstructure is taken up and 24 photomicrographs illustrate the series.

Carbon about 0.2 % Vanadium 0 — 0.68 %. Ferrite grains grow smaller and material harder. With higher carbon up to 0.55 % very slowly cooled, vanadium tends to sorbite rather than pearlite formation. The effect of vanadium on the stability of Martensite not definitely determined.

On the Heat Treatment of Some High-Carbon Steels: W. Campbell. *J. Am. Chem. Soc.*, 28, 1304: *Metallurgie*, III., 741, 781. A series of 6 steels were heated to temperatures from 600–1200° C. Physical properties and microstructure worked out.

Comparison of American and Foreign Rail-Specifications: A. L. Colby. *J. I. S. Inst.*, 1906, III., 189. Deals with the following points: Process of manufacture, chemical composition and analysis, physical properties, drop test, tensile test, dead-weight test, bending test, section, etc. There is a valuable bibliography arranged by years.

Improvements in Rolling Iron and Steel: J. E. York. *J. I. and S. I.*, 1906, III., 307. Gives illustrations of York universal mill and transverse mill, method of work and sections rolled.

The Heat Treatment of Wire: J. D. Brunton. *J. I. S. Inst.*, 1906, II., 142. Two steels carbon 0.75 and 0.83 per cent., and Mn 0.64 and 0.71 per cent. as wire 0.22 and 0.215 in. dia. Half of each was annealed before any cold work was done. After pickling they were drawn through dies with a reduction of 7 per cent., tested, annealed, tested; again pickled, etc., reduced cold through 17 different passes, and tested after each pass. Maximum stress rises from 68 tons sq. in. and 80 tons sq. in. to 152 tons (165 annealed) and 157 tons (165 annealed). Elongation in 8 inches drops from 7 to 3 per cent.

Segregation in Steel Ingots: J. E. Stead. *Proc. Cleveland Inst. or Engs.*, 1905–1906, 163. Deals with macro and microstructure. Sul-

phur segregates most, then phosphorus, then carbon. Manganese and silicon do not segregate to any extent. Compression in the mould the only method to produce sound material.

Influence of the Condition of the Several Varieties of Carbon Upon the Strength of Cast Iron: W. H. Hatfield. *J. I. and S. Inst.*, 1906, II., 157. The author set out to find: (*A*) The condition of the carbon as found in cast irons as cast and heat-treated; (*B*) the influence of silicon upon the strength of cast irons as cast; (*C*) the influence of initial casting temperature upon the strength of cast irons as cast and heat-treated; (*D*) the influence of the condition of the carbon upon the strength as cast; (*E*) after heat treatment. He concludes that the conditions in which the carbon exists determine to a great extent the strength, white irons being the strongest. Grey irons give low results, their strength being dependent on the amount of combined carbon. Grey irons are weakened by annealing, white irons are rendered much stronger, their strength being influenced by the condition of the free carbon, and by the amount of combined carbon present in the form of pearlite.

The Preparation of Carbon-Free Ferro-Manganese: Roberts and Wraith. *J. I. and S. Inst.*, 1906, II., 229. Describe experiments to produce carbon-free ferro-manganese, at a low cost. The best process is dependent on the carbide and oxide reaction using a basic lining (not exceeding 10 per cent. SiO_2) and slag as high as possible in manganous oxide consistent with fluidity. This reaction takes place approximately at 1,670° C.

Cementation: Ledebur, *Stahl und Eisen*, XXVI., 72. Is a reply to an article by Guillet, disproving most of his conclusions. Saniter treated pure iron wire in charcoal at 900° C. In 7 days the metal absorbed 1.54 per cent. carbon. In 7 more days it absorbed another 1.15 per cent. and during a third like period it took up 0.16 per cent. carbon. This shows that the process slows up as it approaches the saturation point for the particular temperature used. The work of Mannesmann is quoted. Cementation is the result of the direct action of carbon on iron above 750° C. Gives results of cementation in charcoal from wood, in sugar charcoal, in fresh wood charcoal and in that used once, of Lancashire iron just below 950° C. for 408 hours. Fresh wood charcoal gave 1.45 per cent., sugar charcoal 1.38 per cent.

Recent Processes in Machine Moulding Practice: Ph. Bonvillain. *J. I. and S. Inst.*, 1906, III., 334. Describes universal moulding machinery which is practical and effects a considerable saving. Castings always same shape, weight, etc.

Test of Hardness by the Brinell Method at the Brussels Congress: H. Le Chatelier. *Revue de Mét.*, III., 689. Consists of pressing a chilled steel ball onto the metal to be tested with a known weight. The *number of hardness* is obtained by dividing the load by the surface of the spherical impression produced. This number, under like conditions, is proportional to the tenacity. Brinell recommends for testing iron the use of balls 10 mm. in dia. under a pressure of 3,000 kg. Benedicks [*Rev. de Mét.*, I. (2), 540], determined the influence of

variations of pressure and of the diameter of the ball. This was repeated by Brinell and Dillner and presented to the congress. Breuil presented to the congress results rather contrary, however. Test of hardness by impact. Guillery's method is described (*Rev. de Mét. Memoires*, I., 405). Brinell has constructed an apparatus. A weight of 5 kg. drops in a steel tube from a known height and strikes a cylinder carrying a ball of 100 mm. dia. The height of fall is 0.45 meters. The impression gives the number of hardness.

LEAD.

Present Position of Lead Smelting in Germany: F. T. Havard. *E. and M. J.*, 82, 337. Predicts the shutting down of most plants. Most of ore is in form of concentrates from Broken Hill, imported by Metallgesellschaft, of Frankfurt, and Main and Beer Sondheimer & Co. The former own patent rights of the H. and H. process.

Friedrichshütte at Tarnowitz smelts 70,000 tons from its own mines. New flue dust system. Clausthal smelts about 14,000 tons local ores, work lead refined at Lautenthal. Alternau treats lead-copper matte from Hartz and the Rhenish smelters. The copper works of Oker and Mansfeld make some lead, 5,000 and 500 tons per an. Freiberg makes only 5,000 tons of lead, but ranks 3 in silver production. Freiberg, Braubach and Anhalt, use Pilz; Tarnowitz, Walter Croneck Hütte and Clausthal, the round furnace with side feed and stack; the Rhenish works the oblong furnace or Raschette-ofen.

The Magdalena Smelter, Oaxaca, Mexico: C. L. Logue. *E. and M. J.*, 82, 745. New smelter 20 miles from Oaxaca. Ores carbonates of lead, high iron. 200 bars of bullion per day.

Smelting at Kansas City: E. and M. J., 82, 881. The consolidated Kansas City S. and R. Co. smelted silver-lead ores from Sierra Mojada, Mexico, and refined much work-lead and matte from Colorado, Mexico and elsewhere. After the A. S. and R. centralized the industry there was no need for both the Omaha and the Argentine refineries. The Kansas City plant was dismantled, and its hydrometallurgical processes for copper sulphate from matte and zinc sulphate as a by product in lead refining are things of the past.

The United Zinc and Chemical Co. makes sulphuric acid from Leadville zinc concentrates of the American Zinc Extraction Co. who operate Yak mill — 200 tons ore a day from Moyer mine — International Magnetic Separators. At Argentine, concentrates roasted in Hegeler and Hofmann-McDougall furnaces. Burned ore shipped to Iola, Kansas, for reduction to spelter.

Smelting Rates in Nevada: E. and M. J., 82, 1079. Gives rates of A. S. and R. Co.: Silver ore $5 on $14 ore or under; $6 on $14 to $20 ore; $6.50 on $20 to $25 ore. Ore from 0.2–5 per cent. Cu; increased allowances from $1.50 to $2.25 per unit (20 lbs.); ore from 5 to 10 per cent. Cu from $1.75 to $2.50. All ore over 10 per cent. Cu from $2 to $2.75.

Lime-Roasting of Galena: W. R. Ingalls. *Bull. A. I. M. E.*, 1906, 681. Deals with the Huntington-Heberlein process and method

of working, then takes up the Carmichel-Bradford and the Savelsberg processes.

The Pot-Roasting of Ore: L. S. Austin. *M. and Sci. Press*, 93, 511. Remarks on the H. and H. process.

On the Formation of Fume and Furnace Deposits in Lead Smelting: Doeltz and Graumann. *Metallurgie*, III, 441. Galena is more volatile than lead oxide: at 860° distills at rate of 18 per cent. per hr. Lead sulphate is only slightly volatile but decomposes at 1,000° C. What sulphate is found in dust chambers is formed by reaction of sulphur trioxide and lead oxide or by the oxidation of lead sulphide.

Smelter Administration: H. Haas. *E. and M. J.*, 82, 1162. Deals with the advantage of a systematic method of keeping accounts at metallurgical works.

Metallurgical Accounts: P. H. Argall. *M. and Sci. Press*, 93, 573, 722, 750. Gives method of keeping accounts in smelting with various record books and sheets.

Tin.

Tin Smelting at Launceston, Tasmania: J. D. Millen. Annual Report Zeehan School of Mines and Metallurgy. *E. and M. J.*, 82, 1135. Mt. Bischoff works receive 70 per cent. ore. Reverberatory furnaces take 50 cwts. of ore, 10 cwts. small coal per charge. Reduction in 8 hrs. Slags skimmed off and metal tapped into reservoir. Another charge then run. Metal after cooling somewhat is ladled into large kettle and poled — 99.89 fine. Slags resmelted.

Zinc.

The Mineral Point Zinc Works: E. and M. J., 82, 388. Branch of N. J. Zinc Co. makes sulphuric acid and zinc oxide. Buys concentrates of blende and marcasite — magnetic separation — concentrates shipped to DePue Smelter, Ill. Oxide plant. 36 double Wetherill furnaces.

The Lungwitz Process of Zinc Smelting: F. W. Gordon. *E. and M. J.*, 81, 795, 82, 71. Describes the blast furnace at Warren, N. H., built for a working pressure of 100 lbs. per sq. in., the difficulties, etc., in determining the right slag to use, tests to determine the pressures restraining zinc ebullition at various temperatures. Lead ore is charged with the zinc ore and an alloy is formed much more difficult to vaporize than pure zinc.

On the Volatility of Zinc Blende: Doeltz and Graumann. *Metallurgie*, III., 442. Six experiments of heating blende to 1,000–1,200° C. show blende to be very volatile at 1,200° C.

On the Distillation of Roasted Blende and Calcining Calamine: Doeltz and Graumann. *Metallurgie*, III., 443. Deals with the reaction $ZnO + CO_2 = ZnCO_3$. Easily occurs when moist. Carbonate decomposes at 137° c.

The Decomposition and Formation of Zinc Sulphate in the Roasting of Blende: Doeltz and Graumann. *Metallurgie*, III., 445. Similar work

to that of Hofman (*T. A. I. M. E.*, 1905, 811), above 700° C. decomposition occurs, with the formation of mixtures of ZnO and $ZnSO_4$ and not the basic sulphate.

METALLOGRAPHY, PYROMETRY.

The Electric Arc Applied to Pyrometry: M. Simonis. *Spreehsaal*, 39, 1283. Abs. *Rev. de Mét.*, III., p. 799. Shows an electric arc furnace 35 mm. x 35 mm. for work with Seger cones. 70 volts and 200 amps. melt alumina in six minutes.

The Bristol Recording Pyrometer. E. and M. J., 82, 982. Dead beat galvanometer by Weston Electrical Instrument Co. Recording arm moves just in front of a revolving chart with smoked surface, which vibrates. Couples for temperatures up to 2,000° F. made in expensive alloys. Above 2,000° F. of platinum — platinum rhodium. Extensions used to cut down cost, and are such that the two secondary thermo-electric effects neutralize each other, if not heated above 1,200° F. A mercury compensator takes care of change of temperature of cold junction.

The Practical Application of Metallography in the Works: Heyn. *Stahl und Eisen*, 1906, 580. Abs. *Rev. de Mét.*, III., 658. It reveals differences of chemical composition, especially segregation, by etching with copper ammonium chloride. The presence of oxygen in steel, of dissolved gases, thermal and mechanical treatment, etc., can all be followed by the aid of metallography. The paper deals with experiments on the temperatures of tempering.

Practical Application of Microscopic Metallography in the Works: H. le Chatelier. *Revue de Mét.*, III., 493. First are given examples of good and bad brasses, cast machine tools, tool steels. Next examples of porosity, slag, graphite, sulphide of iron in iron and steel are given and bronzes, iron and carbon, iron and phosphorus, iron and silicon, are shown, and their composition estimated. Then structure is taken up and lastly uses of metallography are given.

Metallographic Research in the Foundry: E. Heyn, *Stahl und Eisen*, XXVI., 1295, 1386. Abs. *Rev. et Mét.*, IV., 69. Deals the scientific investigation of cast iron. Two systems: (1) Iron and carbide — white iron and steel; (2) iron and graphite. This latter is the more stable in the solid. Silicon promotes formation of (2). Bending strength of cast-irons of varying thickness depends mostly on the graphite content. The thinnest bars show the greatest strength. The size of the graphite crystals is an important factor. The process of solidification is taken up. Next the bronzes are considered, the reduction of copper oxide in copper by the addition of tin and zinc. Phosphorus reduces oxide of tin in bronze and forms a liquid phosphate which is easily got rid of. The mode of crystallization of mixed crystals or solid solutions in the copper-rich bronzes and the effect of rate of cooling are discussed.

Etching Reagents for Steel Metallography: Kourbatoff. *Rev. de Mét.*, III., 648. Four reagents were given in *Rev. de Mét.*, II., 169. In visiting several metallographic laboratories the 4 per cent. nitric acid in iso-amyl alcohol solution failed to distinguish Troostite and Sorbite.

The reason lies in using acetic acid instead of its anhydride $(C_2H_3O)_2O$. The method is as follows: (1) Dissolve 4 per cent. HNO_3 (1.32) in acetic anhydride. (2) Mix equal parts of methyl, ethyl and iso-amyl alcohol. Just before use add one part of (1) to three parts of (2). Up to ten minutes only the Sorbite and Troostite will be colored.

Speed of Attack of Metallographic Reagents: P. Lejeune. *Revue de Mét.*, III., 426. Mentions Kourbatoff's paper on metallographic reagents (*Revue de Mét.*, March, 1905). A 4 per cent. solution of picric acid in absolute alcohol is taken as standard. Acetonitrile, proprionitrile methyl alcohol, ethyl alcohol are solvents placed in order of rapidity of attack. The greater the dissociation the more rapid the attack.

Equilibrium Diagram of the Iron Carbon Series: G. Charpy. *C. R. Ac. des Sciences*, CXLI., 948. Discusses the Roozeboom diagram and makes certain corrections in the same. The eutectic of mixed crystals and graphite and that of mixed crystals and cementite freeze very close to 1150° C.

On the Constitution of Cast Iron: Goerens. *Stahl und Eisen*, XXVI., 397. Abs. *Rev. de Mét.*, III., 609. Deals with the relation between constitution and mechanical properties. Graphite diminishes the strength, which is a maximum with 1 per cent. carbon in the combined form, *i. e.*, the steel groundmass is entirely pearlite, and as small an amount of graphite as fine as possible. By quenching cast iron we can obtain austenite, martensite and troostite, as in steel.

Equilibrium and Structures in the Iron Carbon System: C. Benedicks. *Metallurgie*, III., 393, 425, 466. Abs. *Rev. de Mét.*, IV., 135. Discusses the Roberts-Austen-Rooseboom diagram and the reaction at 1000° C. whereby martensite (mixed crystals) + graphite form cementite. He moves the line aE denoting the separation of graphite to the left and makes it parallel to the line $E'S$ denoting the separation of cementite. The horizontal line EF is suppressed and the reaction there denied. The whole is reduced to two systems: that of cementite, metastable; that of graphite, stable. The paper is illustrated by numerous microphotographs.

The Constitution of Iron-Carbon Alloys: A. Sauveur. *J. I. and S. I.*, IV., 1906, 495. A discussion of the Roberts-Austen-Rooseboom Diagram, followed by experiments to show that graphite once formed does not react with austenite to form cementite, but is inert. Then concludes that austenite is a solid solution of carbon in γ-iron, martensite a solid solution of carbon in β-iron, troostite a solid solution of carbon in α-iron and pearlite the iron-carbide eutectoid.

On the Theory of the Formation of Graphite: F. Wüst. *Metallurgie*, III., 757. The formation of graphite depends on the rate of cooling and the amount of carbon present rather than on the presence of silicon, etc. Silicon lengthens the period of formation, manganese shortens it. Six excellent photographs given.

On the Influence of Silicon on the Iron-Carbon System: Wüst and Peterson. *Metallurgie*, III., 811. Sixteen melts ranging from 0.13 per cent. Si to 26.93 per cent. were made, of which the following are numbers 1, 5, 8 and 12: With 0.13 per cent. Si, 4.29 per cent. C.,

f.p. = 1,138° C.; with 1.14 per cent. Si, 3.96 per cent. C., f.p. = 1,160° C.; with 2.68 per cent. Si, 3.56 per cent. C., f.p. = 1,185° C; with 4.86 per cent. Si, 3.08 per cent. C., f.p. = 1,210° C. The freezing point shows a rise from 1,138° to 1,255° C. The graphite increases from 1.43 per cent. in 1 to 2.51 in 5 and 2.93 per cent. in No. 8 and so forth. Eighteen cooling curves are given. A table showing relation between the percentage Si, the time and temperature interval of freezing, the percentage graphite and the percentage graphite in the total carbon. This latter bears no regular relation to the percentage silicon. The Ar_3 point shows a rise to 770° C. with 3.25 per cent. Si.

The Crystallography of Iron: F. Osmond and G. Cartaud. *J. I. and S. Inst.*, 1906, III., 444. *Revue de Mét.*, III., 653. By studying mechanical twinning, twinning caused by annealing, faces of maximum hardness, of easiest etching, etc., the three allotropic varieties of iron, although they all crystallize in the cubic system, present well marked specific characters and cannot have the same internal structure. Illustrations of deformation figures, corrosion figures, etc., are given.

The Work of Fournel and the Lower Limit of A_2: F. Osmond. *Revue de Mét.*, III., 551. The lower limit of A_2 appears to coincide with the appearance of brittleness in the blue heat. The presence of beta iron would cause brittleness.

Hardening of Steel: Oester Zeit. Berg- und Hüttenweke, LIV., 234. A list of all papers, etc., on the hardening of steel which have appeared in this periodical since its first issue.

Heyn's Experiments on Hardening and Tempering of Steel: F. Osmond. *Rev. de Mét.*, III., 6, 21. Discusses Heyn's work to determine troostite and sorbite (Mitt. aus dem Kön. Materialprüfungsamt Gross-Litchterfelde West., 1906, p. 29). Steel used was 0.95 per cent. carbon, eutectoid. Quenched from 900° C. gave martensite pure. Was tempered in different ways — boiling water, oil at 200° C., etc. Hardness measured by Martens sclerometer. Planing and pulverizing. Attack for 10 minutes by 1 per cent. HCl in alcohol. Solubility in 1 per cent. H_2SO_4. State of the carbon. Microstructure. Martensite is a mixture of alpha iron and allotropic iron, carbon in the hardening form. Troostite a transition, the allotropic iron disappearing, carbon still "carbone de trempe." Osmondite is alpha iron with carbon in the hardening form. Sorbite a transition form in which the carbon passes into the form of carbide and the alpha iron changes from granular to reheated or crystalline, with the liquation of two constituents. Pearlite is a mixture of cementite and crystalline alpha iron.

A Study of the Tempering of Steel: P. Lejeune. *Revue de Mét.*, III., 528. The double galvanometer of Saladin was used. Cylinders of steel 5 cm. in dia. were drilled in the center and half way to the outside. Two couples were fixed in them and the difference in temperature of the two places measured. A cryptol furnace was employed to heat the specimens. A third couple read the temperature of the outside of the specimen. Quenching bath of three liters used.

Deformation and Fracture in Iron and Steel: W. Rosenhain. *J. I.*

and S. Inst., 1906, II., 189. First makes some further observations on slip-bands and then takes up fractures in iron and steel. One eighth inch of copper was deposited on the fractured surface and a section then cut, using magnesia, prepared from calcined magnesium carbonate, for polishing. A Staffordshire wrought iron of medium quality, a very pure Swedish iron and a mild steel of 0.15 per cent. C. and 0.45 per cent. Mn were examined. Excellent photomicrographs illustrate the paper.

On Some Microscopic Effects Produced on Metals by Strain: F. Rogers. *Rev. de Mét.*, III., 518. The nature of fatigue has been studied in a series of 4 steels, C = 0.14 to 0.58 after heat treatment at temperatures between 600 and 1,200° C.

Hardness of the Constituents of Iron and Steel: H. C. Boynton. *J. I. and S. Inst.*, 1906, II., 287. Describes work with Jaggar's microsclerometer to determine the hardness of the constituents of a series running from electrolytic iron to grey Swedish pig iron with 4.55 per cent. carbon. The average hardness ratio with ferrite of electrolytic iron as 1 runs: Ferrite 1.03 : pearlite 3.8–4.2. Sorbite 5–54. Troostite 88. Martensite 39–262 : Austenite 103. Cementite 273, in round numbers.

Aluminium-Bismuth and Aluminium-Tin Alloys: A. G. C. Gwyer. *Zeit. Anorg. Chem.*, 49, 311. Finds that the alloys of Al and Sn consist of dendrites of Al in a groundmass or eutectic of tin. The aluminium-bismuth alloys separate into two conjugate solutions, the lighter freezing at 650° C., the heavier 274° C. The solubilities are 0.5 at. per cent. bismuth and 8 at. per cent. aluminium.

The Antimony-Cadmium Alloys: W. Treitschke. *Zeit. Anorg. Chem.*, 50, 217. A compound SbCd forms at 51.6 per cent. Sb and 456° C. Eutectics (1) at 60 per cent. Sb and about 453° C., and (2) at 8 per cent. Sb and about 293° C. An unstable compound Sb_2Cd_3 may form.

Alloys of Nickel and Antimony: K. Lossew. *Zeit. Anorg. Chem.*, 49, 58. Two compounds formed NiSb 1158° C. and Ni_5Sb_2 1170° C. Just above the eutectic temperature NiSb changes to Ni_4Sb_5, Eutectic of Sb and Ni_4Sb_5 at 611° C. and 2.7 per cent. Ni, eutectic of NiSb and Ni_5Sb_2 at 1072° C. and 47.6 per cent. Ni, eutectic of Ni and Ni_5Sb_2 at 1100° C. and 66.14 per cent. Ni, but at 677° C. Ni_4Sb forms in the solid. Ni_5Sb_2 has an inversion point at 580° C. in presence of NiSb.

The Alloys of Antimony and Tellurium and of Antimony and Selenium: Pelabon. *C. R. Ac. des Sciences*, CXLII., 207. Antimony and tellurium form a compound Sb_2Te_3 which melts just above 600° C., and forms eutectics with antimony and with tellurium. Antimony and selenium form a compound SbSe which alloys with selenium but forms two conjugate solutions, freezing at 566° and 518° C. The compound freezes at 600° C.

Antimony-Thallium Alloys: R. S. Williams. *Zeit. Anorg. Chem.*, 50, 127. Antimony 630° C. and thallium 301° C. which has a critical point 226° C., form a V-shaped curve meeting at 20 per cent. Sb. The series show two halts throughout at 195° C. and 187° C. The

upper is the freezing of the eutectic, the lower a change in the solid whereby the solid solution 22 per cent. Sb reacts with Sb or Tl to form $SbTl_3$.

The Alloys of Antimony and Tin: F. E. Gallagher. *J. Phys. Chem.*, X., 93. Reinders found the alloys to consist of (1) a solid solution rich in Sb; (2) the compound Sb_4Sn_3, possibly Sb_3Sn_4; (3) SbSn; (4) a solid solution rich in tin. The uncertainty of the compound Sb_4Sn_3 was the cause of the new research. The author found that there were no compounds but four sets of solid solutions, with inversion points at 430°, 319° and 243° C. The second or β-crystals are instable below 313° C.

Zink-Antimony Alloys: S. F. Zemczuznyj. *Zeits. Anorg. Chem.*, 49, 384. Zinc and Zn_3Sb_2 566° C. form a eutectic 1.21 at. per cent. Sb at 412.5° C. Zn_3Sb_2 and Sb form a eutectic at 62 per cent. and 482° C. A reaction $Zn_3Sb_2 + Sb = 3ZnSb$ occurs at 537° C. ZnSb and Sb form a eutectic at 505° C. and 68.5 at. per cent. Sb. By surfusion ZnSb is not formed at 537° C. (See Mönkemeyer, *Zeit. Anorg. Chem.*, 43, 187.)

The Copper-Cadmium Alloys: R. Sahmen. *Zeit. Anorg. Chem.*, 49, 301. Cadmium and Cd_3Cu_2 564° C. form a eutectic at 98 per cent. Cd and 314° C. Cu_2Cd_3 and Cu_2Cd form a eutectic at 59.5 per cent. Cd and 542° C. Between 0 and 46 per cent. Cd we have Cu in a groundmass of Cu_3Cd whose formation temperature is 550° C.

The Constitution of Copper-Tin Alloys: Shepherd and Blough. *J. Phys. Chem.*, X., 630. Using Bancroft's analytical method for finding the compositions of the solid phases and lead as the third component, the authors conclude that the phases which can co-exist with the melt are α, β and γ solid solutions, the compound Cu_3Sn, the ϵ solid solution and pure tin. Below 600° C. the δ solid solution can exist (this was supposed to be Cu_4Sn).

The Alloys of Gold with Bismuth and Antimony: R. Vogel. *Zeit. Anorg. Chem.*, 50, 145. Gold and bismuth form a eutectic at 82 per cent. Bi and 240° C. Gold holds 4 per cent. Bi in solid solution. Gold and antimony form a compound $AuSb_2$. Gold and $AuSb_2$ 55 per cent. Sb and 460° C. form a eutectic at 24 per cent. Sb. 360° C. Between 55 and 100 per cent. Sb we find Sb in a groundmass of $AuSb_2$.

The Alloys of Silver with Thallium, Bismuth and Antimony: G. I. Petrenko. *Zeit. anorg. Chem.*, 50, 133. From 0 to 10 per cent. Tl silver forms solid solutions. At. 2.5 per cent. Ag and 287° C. we have the entectic whilst at 227° C. we have the change from β- to α-Thallium.

Bismuth 269° and silver 961.5° C. form a entectic 2.5 per cent. Ag at 262° C. There is marked bend in the curve at 40 per cent. Silver holds about 5 per cent. Bi in solid solution.

Silver and antimony form a compound Ag_3Sb. Antimony and Ag_3Sb form a entectic 45 per cent. Sb at 453° C. Ag_3Sb at 27.07 per cent. Sb and silver form a series of solid solutions of silver with 15 per cent. Sb in solution and reaction temperatures 559° C.

Alloys of Lead and Calcium: Hackspill. *C. R. Ac. des Sci.*,

CXLIII., 227. By adding metallic calcium to chloride of lead and an alloy running 21 per cent. Ca was formed with explosion. Or calcium chloride is electrolysed and a lead cathode used, a little calcium fluoride helps. A compound Pb_3Ca_2 is indicated, melting at 775° C.

Alloys of Magnesium and Cadmium, Zinc, Bismuth, Antimony: G. Grube. *Zeit. anorg. Chem.*, 49, 72. No maximum at MgCd as found by Boudouard. MgCd forms a series of solid solutions with Mg and Cd. MgCd shows change-point at 250° C. Maximum for $MgZn_2$ melting at 595° C. At about 51 per cent. Zn and 345° C. we have the eutectic with Mg and at 97 per cent. Zn and 368° C. that with pure zinc.

Maximum for Bi_2Mg_3 at 715° C. Forms eutectic at 550° C. and 65 per cent. Bi with pure Mg, but in alloys with over 65 per cent. Bi it freezes out in a groundmass of pure Bi. Oxidation of compound in moist air.

Maximum for Sb_2Mg_3 at 961° C. Forms eutectic at 625° C. and about 39 per cent. Sb with pure magnesium. At 595° and 95 per cent. it forms a eutectic with antimony.

The Alloys of Magnesium and Silver: S. F. Zemczuznyj. *Zeit. anorg. Chem.*, 49, 400. Silver and MgAg form a eutectic at 756° C. and 65.9 at. per cent. Ag, but Ag holds 28.15 per cent. Mg in solid solution and MgAg holds 12.6 at. per cent. Ag. in solution. Mg_3Ag and Mg form a eutectic at 17.8 at. per cent. Ag and 469° C. Between 34.57 at. per cent. and 25 at. per cent. MgAg (with 15½ per cent. Mg in solution) occurs in a groundmass of Mg_3Ag whose formation point is 492° C.

Sodium-Lead, Sodium-Cadmium, Sodium-Bismuth and Sodium-Antimony Alloys: C. H. Mathewson. *Zeit. anorg. Chem.*, 50, 171. The constituents of the lead-sodium alloys are: (1) Na at 97.5° C.; (2) Na_4Pb 386° C.; (3) Na_2Pb at 405° C.; (4) NaPb at 367° C.; (5) Na_2Pb_5 at 319° C. and (6) Pb at 326.9° C. The eutectics are: (1) $Na_4Pb + Na_2Pb$ at 373° C. and 25.8 per cent. Na; (2) $Na_2Pb + NaPb$ at 329° C. and 13.6 per cent. Na; (3) $NaPb + Na_2Pb_5$ at 301° C. and 6.2 per cent. Na and (4) $Na_2Pb_5 + Pb$ at 307° C. and 2.7 per cent. Na.

The constituents of the sodium-cadmium alloys are: (1) Na; (2) $NaCd_2$ at 385° C. and 9.3 per cent. Na; (3) $NaCd_5$ at 360° C. and 3.8 per cent. Na; (4) Cd at 322° C. The eutectics are: (1) $Na + NaCd_2$ at 95° C. and 96.1 per cent. Na; (2) $NaCd_2 + NaCd_5$ at 346° C. and 5.2 per cent. Na; (3) $NaCd_5 + Cd$ at 285° C. and 1.2 per cent. Na. Two conjugate solutions are formed between 24 and 33 per cent. Na.

The alloys of sodium and bismuth show two compounds Na_3Bi at 775° C. and NaBi which forms at 445° C. by reaction of Na_3Bi with the melt. NaBi and Bi form a eutectic at 218° C. and 3 per cent. Na.

The alloys of sodium and antimony show two compounds Na_3Sb at 856° C and NaSb at 465° C. Eutectic of Na_3Sb and NaSb at 435° C. and 19.3 per cent. Na; that of NaSb and Sb at 400° C. and 11.1 per cent. Na.

Silicides of Nickel: W. Guertler and G. Tammann. *Zt. anorg. Chem.*, 49, 93. Ni with 5 per cent. Si in solid solution and Ni_2Si form a eutectic, 10.6 per cent. Si at 1,153° C, at 1,125° a reaction occurs and Ni_3Si is formed. Ni_2Si 1,309° and NiSi 1,000° C. form a eutectic at 27 per cent. Si and 957° C. (The Ni_2Si forms solid solutions with Ni and NiSi to the extent of several per cent.) At a temperature around 800° the solid solution breaks down with the formation of Ni_3Si_2. Between 32.4 and 41.8 per cent. Si the alloys consist of NiSi or Ni_2Si_3 in the eutectic which freezes at 975°. From 41.8–100 per cent. Si we have Si in a groundmass of Ni_2Si_3 which shows an inversion at 1,025° C.

The Compounds of Manganese with Silicon: F. Doerinckel. *Zeits. anorg. Chem.*, 50, 117. Manganese 1,244° C., and Mn_2Si 1,316° C., and MnSi 1,280°, and silicon 1,458° C. Silicon and MnSi form a eutectic 50 per cent. Si, 1,136° C. MnSi and Mn_2Si form a eutectic 30 per cent. Si, 1,239° C. Mn and Si form a series of solid solutions up to 10 per cent. Si beyond which we have the eutectic with Mn_2Si at about 11 per cent. and 1,075° C.

The Alloys of Zinc and Iron: S. Wologdine. *Revue de Mét.*, III., 701. Have no industrial application because of brittleness. Special brasses contain iron however. In galvanizing baths an alloy separates out containing 4.3 per cent. Fe. With a higher temperature we get one containing 9.5 per cent. Fe, 0.4 per cent. Pb well crystallized, soluble in acetic acid. Le Chatelier isolated crystals of $FeZn_{10}$. Alloys made from galvanized iron wire and zinc heated under charcoal for 1 hour between 700 and 800° C. Pouring off the liquid, and cooling, a product with 8 per cent. Fe was obtained. This alloy was used to prepare the others, and is $FeZn_{10}$ freezing at 750° C. Between this point and pure zinc the alloys consist of crystals of $FeZn_{10}$ in a groundmass of zinc.

Zinc and Arsenic: Freidrick and Leroux. *Metallurgie*, III., 477. Alloys up to 13.9 per cent. As (f.p. 853° C.) were made. All alloys gave a eutectic point at 419° C. showing that the groundmass was pure zinc.

The Equilibrium Diagram for Iron and Sulphur: Tvietschke and Tammann. *Zeit. anorg. Chem.*, 49, 320. Iron and FeS form a eutectic at 16 per cent. Fe and 970° C. The solubility curve cuts the iron freezing branch at 1,400° C. and at 92 per cent. and 20 per cent. Fe. Above 780° C. iron holds 4 per cent. S in solid solution but rejects it as FeS at this temperature being then changed over into the α form. FeS holds 2 per cent. Fe in solid solution and has an inversion temperature of 130° C.

Sulphide, Selenide and Telluride of Tin: Pelabon. *C. R. Ac. des Sciences*, CXLII., 1147. The curves of fusibility indicate the existence of the compounds SnS, SnSe and SnTe.

Sulphide of Antimony and Antimony: Chrétien and Guinchant. *C. R. Ac. des Sci.*, CXLII., 709. Determine the densities at high temperatures. On melting, the sulphide expands about 17 per cent.

Antimony and its sulphide are not completely miscible at high temperatures. The solubilities are given.

On the Nature of Copper Mattes: P. Röntgen. *Metallurgie*, III., 479. A curve with three maxima was obtained: (*a*) Cu_2S, 1085° C.; (*b*) eutectic of *a* and *c*, 21.8 FeS, 995° C.; (*c*) $(Cu_2S)_2(FeS)_2$ 26 per cent. FeS, 1060° C.; (*d*) eutectic of *c* and *e*, 32 per cent. FeS, 1000° C.; (*e*) $Cu_2S \cdot FeS$, 36 per cent. FeS, 1030° C.; (*f*) eutectic *e* and *g*, 50 per cent. FeS, 943° C.; (*g*) $(Cu_2S)_3(FeS)_5$ 58 per cent. FeS, 1080° C.; (*h*) eutectic *g* and FeS, 67 per cent. FeS, 895° C.; (*i*) FeS, 1133° C.

Lead Mattes: W. Weidmann. *Metallurgie*, III., 660. Resistance furnace used. PbS 970° C. and FeS 1137° C. form a eutectic at 26 per cent. FeS and 784° C. No compounds formed.

Non-ferrous Magnetic Alloys: Haupt. *Chem. Centr.*, 1906, I., 906. At high temperature all metals lose magnetism. Iron about 750° C. Nickel 400°. In AlMn bronzes the temperature rises with the Mn. The magnetic properties are maximum when the manganese and aluminium are present in atomic proportions. Lead increases the effect.

General.

Electric Smelting of Sulfide Ore and Furnace Product Direct to Metal: C. Rehmer. *Metallurgie*, III., 549, 596.

I,, Molybdenum sulphide. (1) Alone. Gives charges and metal produced as molybdenum 90 per cent. Ferro-molybdenum 50 per cent. Chrome-molybdenum 55 + 35 per cent. Nickel molybdenum 70 + 25 per cent. approx. Manganese-molybdenum 40 + 50 per cent. Copper-molybdenum 15 + 70 per cent. (2) From sulphides (*a*) Nickel matte 50 per cent. alloy and 70 Ni 30 Mo. approx. (*b*) Copper matte — Cu 14 per cent., Mo 68 per cent. (*c*) Nickel and copper matte. — Metal Ni 33 per cent., Cu 16 per cent., Mo 36 per cent. approx.

II., Nickel Matte. Metal ran Ni 92–96 per cent.

German Technical Schools: A. Pelletan. *Rev. de Mét.*, III., 589. There are 6 higher technical schools "Hochschule" — Charlottenbourg, Munich, Darmstadt, Carlsruhe, Hanover, Stuttgart, Dresden, Aix-la-Chapelle, Dantzig and Brunswick. Three "Bergakademie," Freiberg, Berlin and Clausthal. Gives synopsis of courses and plans of some laboratories.

MEETING OF THE COLUMIA CHAPTER, SOCIETY OF THE SIGMA XI.

A regular meeting of the Columbia Chapter of the society was held in Earl Hall on the evening of May 2, for the purpose of electing officers and initiating those candidates recently elected to membership. The officers for the ensuing term of two years are: President, Dean Hallock of the School of Pure Science; Vice-president, Dr. C. P. Berkey, of the Department of Geology; Corresponding Secretary, Dr. C. E. Lucke, of the Department of Mechanical Engineering; and Secretary-Treasurer, Chas. E. Morrison, of the Department of Civil Engineering. No scientific papers were presented but the initiates were addressed by Dean Hallock, Professor Kemp of the Department of Geology, and Professor Underwood of the Department of Botany; that of the latter follows:

Nearly thirty-five years ago there were two ragged boys in the streets of two of our southern cities; one was earning a scanty living in the streets of Nashville, the other was a newsboy on the streets of Columbia, Missouri. The wheel of fortune has been made to turn by earnest endeavor, and to-day these two humble boys are men of science; one is the presiding genius at the head of a great observatory; the other probably stimulates more wide-reaching research than any other man in America in the Bureau of Plant Industry at Washington. The story of these two men is a genuine confirmation of the principle, that men of science, like poets, are born, not made; even the old label "made in Germany," once somewhat potent in scientific and other educational circles, has largely lost its glamour in the modern development of the American University.

Possibly the undiscerning eye would not have detected in the older of these two southern boys any unusual signs to betoken a budding scientist. He was alert to see all that was going on; his mind was open to new things; but behind his mind there was a soul that only waited to be kindled into an undying fire. The occasion came in the form of a peripatetic street-telescope man, for whom our hero did some menial service receiving as a reward the privilege of looking at the stars through a shaky street instrument. One look was the spark that kindled the ready tinder in the boy's soul, and he was no longer an errand boy — he was an embryo astronomer; he immediately ransacked the old town library for information about the stars, and drew out the ancient and dust-covered volumes of Dick's "Celestial Scenery" and "Sidereal Heavens" and devoured them in the moments snatched from his irregular work; these only fanned to a flame the fire already kindled. His next scanty earnings were hoarded and went into the purchase of a second-hand two-inch telescope, and night after night he studied the heavens behind his little glass. After a little, with a larger instrument for which he had exchanged his first two-inch refractor, he commenced

sweeping the heavens for comets. Night after night, long after his companions slept, he crouched behind his glass, and his efforts were finally rewarded by the discovery of a new comet. From this point on, his career opened up before him; friends arose through whom he was enabled to prepare for college and finish his course, and from that time his upward progress was assured. The newsboy, who is now the non-political power behind the throne of the agricultural end of the President's Cabinet, had a similar history that need not be detailed here. There is perhaps no other country on God's green earth where two such examples could be duplicated, and it makes one's blood tingle a bit more keenly, to feel that we are citizens of "no mean country" where "honor and shame from no condition rise."

Contrast with this picture if you will, the one you sometimes take home from your laboratory at night, of boys who are in college because "it is the thing you know," who work because they are made to work; boys that either in the schools have been pampered and mollycoddled, or at their homes have been neglected and left to themselves and to the streets, until they have lost alike independence, ambition and initiative, and whose feeble nervous system cannot stand the strain of a two-hour laboratory session without one or more "bracers" in the form of pulls at a cigarette.

The tendency to sham commences early in the educational career. It shows itself in the candidate for admission to college who seeks credit for work hastily accomplished or perhaps never done; in his attempt to be rated higher than his deserts or preparation. It continues through undergraduate work, and sometimes into graduate work even, in the attempt to get something for nothing, to elect "snap" courses instead of solid work, to gain credit on superficiality, in short to attempt to be something one is not. It shows itself later in life in the man who covers his lack of definite information by obscure and misleading, though often glittering, generalities, or his absence of genuine reasons by subtle sophistry and the play of psychological pyrotechnics. How many doctor's theses are the swan songs of a neophyte — the end of endeavor, instead of the beginning of a long series of researches!

There is probably no seal of work accomplished which counts for more, than the publication of the results of genuine research. But judicious publication and padded exploitation are two distinct propositions which differ from each other by a heaven's breadth. There is perhaps no more exaggerated manifestation of sham in scientific circles, than the vociferous exploitation of pseudo-scientific fads and fancies paraded before the public with flashing headlines, in journals more or less tinged with a yellow streak.

Real science is ever vigorous but modest, ever virile but never effusive, thoroughly sincere and earnest but never ostentatious. In its true conditions, like that "greatest thing in the world" science "vaunteth not itself, is not puffed up, doth not behave itself unseemly, seeketh not her own" and in the end "rejoiceth in the truth."

More than on other men, boisterous self-conceit rests unfittingly on men of science. Once in a generation, perhaps only once in a century, there may come a real genius — a man so great that his unconscious

manifestation of greatness may appear to men on a lower plane as intentional self-assertion; but on the ordinary man of science the mantle of self-conceit rests like the lion's skin, scarcely concealing the lean sides of the long-eared animal beneath, whose pedigree though lowly must here be nameless.

There are quacks and charlatans in every field, and scientific circles have never been exempt from them. As I understand it, one of the functions of Sigma Xi is the placing of a distinct brand on the work of those who give promise of being something real in the scientific world; to recognize those who give promise, by work already accomplished, of ability to add something to the world's knowledge. Primarily the man of science is a searcher after truth, and though exceptions sometimes arise, this search is a labor in which, as Agassiz said, one must "lie hard and live low," for science does not yet afford the emoluments commensurate with the preparation and labor she exacts. The man whose lust is gold must seek it in some other field of work. In place of such a compensation science assures a man who loves its labor, a peace and satisfaction that no other life can even approximate, and one that must be experienced to be understood.

Just one other thought. The work a man accomplishes in science must come largely from his own initiative; institutions may foster, laboratories, libraries and museums may furnish facilities, the timely criticism of teachers may save from unfortunate blunders, but the hours of dead work necessary to attain the end must be hours of self-work and self-help. Fellow students, whether associates or teachers, may furnish inspiration and criticism, but the road to attainment in research is a solitary road, and each one must set his pace alone, and overcome its obstacles for himself.

UNIVERSITY NEWS.

DEPARTMENT OF CHEMISTRY.

The past year has been a very busy one in the Chemical Department.

The year opened very sadly with the death after a short illness of Edmund Howd Miller, Professor of Analytical Chemistry and Assaying. His long experience and thorough familiarity with his subject make it very difficult to fill his place. His work has been distributed for the remainder of the year among the following officers: Professor H. C. Sherman, Dr. C. H. Joüet, Dr. F. J. Metzger, and Mr. E. J. Hall.

Professor J. S. C. Wells has been away from the University on leave of absence.

A. J. Mettler, B.S., was appointed Lecturer in Analytical Chemistry (Qualitative) to succeed F. V. D. Cruser, resigned.

O. Kress, B.S., succeeded A. J. Mettler as Assistant in Analytical Chemistry (Quantitative).

K. G. Falk, Ph.D., and J. N. Pring, M.Sc., have served as Honorary Assistants in Physical and Electro-Chemistry respectively.

At the beginning of the second term J. E. Sinclair, B.S., was appointed Lecturer in Analytical Chemistry (Quantitative).

Thirty courses of instruction were given during each half year session, the attendance upon each course varying from two to two hundred and twenty-one (2 to 221).

725 students attended one or more of the courses given:

Columbia College	270
Schools of Applied Science	410
Law School	2
Pure Science, Special	1
Teachers College	9
Pure Science, M.A.	16
Pure Science, Ph.D.	17
	725

683 students received practical instruction in the different laboratories.

The total number of registrations in all the courses of instruction, each unit representing one man taking one course for each half year, was 1,964.

The advanced work of the department continues to increase steadily and has been more systematically provided for in the rearrangement made necessary by the renumbering of courses. Each laboratory now offers one or more courses designed especially for graduate students.

A course in special methods of organic analysis and food investigation, offered this year for the first time and restricted to post-graduates, was elected by ten students, one of whom, Dr. N. E. Goldthwaite, received during the year an important laboratory appointment in the Rockefeller Institute for Medical Research.

In order to minimize the confusion which has prevailed regarding the admission of graduate women to courses in chemistry, it is now provided that all strictly graduate courses (those numbered over 200) shall be open to men and women on equal terms, while any course which is both graduate and professional (numbered 101–200) may be opened to women by the instructor giving the course.

A Jubilee in honor of Sir William Henry Perkin, the discoverer of the first coal-tar color, mauve, was held in New York in October, 1906. Professor Chandler was chairman of the committee in charge of the celebration, and presided at the banquet.

Professor Chandler delivered the following lectures:

On the "Electrochemical Industries at Niagara Falls" before the American Association for the Advancement of Science, at the College of the City of New York, December 29, 1906; same before the Chemistry Teachers Club, on March 9, 1907; on "Ceramics" before the Chemistry Teachers Club, on April 6, 1907.

The University of Göttingen conferred an *ehren Diplom* upon Professor Chandler in September 1906, this being a renewal of the degree of Doctor of Philosophy which Professor Chandler received from that University fifty years ago.

Professor Bogert has been elected President of the American Chemical Society, and Professor Sherman Chairman of the New York Section.

Professor Bogert has also accepted the editorship of the abstracts in organic chemistry for *Chemical Abstracts*, and Drs. Chambers and Falk have been appointed to the board of abstractors.

Professor Morgan has been appointed in charge of chemistry in the Summer Session and will give a lecture course in physical chemistry.

Professor Tucker has served as Chairman of the N. Y. Section, American Electrochemical Society, represented that Society on the General Committee having charge of the winter meetings of chemists in New York, and has recently been elected a member of the Board of Directors of the Society.

Professor Sherman has been made Professor of Organic Analysis, and will offer additional work in organic and sanitary analysis and food chemistry both during the regular academic year and in the Summer Session.

Mr. Hall, who has had charge of all work in Assaying since the death of Professor Miller has been made Instructor in Assaying.

Dr. Chambers has been promoted to an Instructorship in Organic Chemistry.

Dr. Metzger becomes Instructor in Analytical Chemistry and will have charge of those courses in quantitative analysis which were formerly conducted by Professor Miller.

Mr. Kress takes the place of Dr. Metzger as Tutor in General Chemistry.

The investigations which have been published from the department since the last recorded in this QUARTERLY are as follows:

No. 116. The Detection, Determination and Rate of Disappearance of Formaldehyde in Milk. By R. H. Williams and H. C. Sherman.

No. 117. On 5-amino-4-ketodihydroquinazoline and 5-amino-2-

methyl-4-ketodihydroquinazoline. By M. T. Bogert and V. J. Chambers.

No. 118. Proteolysis in Cows' Milk Preserved by Means of Formaldehyde. By W. G. Tice and H. C. Sherman.

No. 119. Some Observations on the Preparation of Metallic Calcium by Electrolysis. By S. A. Tucker and J. B. Whitney.

No. 120. The Osazone Test for Glucose and Fructose as Influenced by Dilution and by the Presence of other Sugars. By H. C. Sherman and R. H. Williams.

No. 121. On 4-aminodimethylorthophthalate and Certain of its Acyl Derivatives. By M. T. Bogert and R. R. Renshaw.

No. 122. The Preparation of Boron Carbide in the Electric Furnace. By S. A. Tucker and H. J. W. Bliss.

No. 123. Researches on Quinazolines (Fifteenth Paper) on 3-aminoquinazoline and the Corresponding 3, 3'-diquinazolyl from 6-nitroacetanthranil and Hydrazine Hydrate. By M. T. Bogert and H. A. Seil.

No. 124. Researches on Quinazolines (Sixteenth Paper). Synthesis of 6-nitro-2-methyl-4-ketodihydroquinazolines from 5-nitroacetanthranil and Primary Amines. By M. T. Bogert and Ellen P. Cook.

No. 125. The Measurement of Temperature in the Formation of Carborundum. By S. A. Tucker and Alexander Lampen.

No. 126. An Electrical Resistance Furnace for the Measurement of Higher Temperatures with Optical Pyrometer. By Alexander Lampen.

No. 127. Platinum Silver Alloys. By J. F. Thompson and E. H. Miller.

No. 128. The Insoluble Chromi-Cyanides. By F. V. D. Cruser and E. H. Miller.

No. 129. Seasonal Variations in the Composition of Cows' Milk. By H. C. Sherman.

No. 130. Researches on Quinazolines (Seventeenth Paper). The Synthesis of Quinazoline Carboxylic Acid from 4-aminoisophthalic Acid and from Aminoterephthalic Acid. By M. T. Bogert, J. D. Wiggin and J. E. Sinclair.

No 131. Researches on Quinazolines (Eighteenth Paper). On 2, 3-dialkyl-4-quinazolones and the Products Obtained by Alkylating 2-alkyl-4-quinazolones (2-alkyl-4-hydroxy-quinazolines). By M. T. Bogert and H. A. Seil.

No. 132. Researches on Quinazolines (Nineteenth Paper). The Synthesis of 1, 3, 6, 8-naphthotetrazines from p-diamino-terephthalic Acid and from Certain of its Derivatives. By M. T. Bogert and J. M. Nelson.

No. 133. Some new Double Phosphates of Iron (Ferric) and Aluminium. By L. J. Cohen.

No. 134. The Calculation of some Chemical Equilibria. By K. G. Falk.

No. 135. Iron in Food and its Functions in Nutrition. By H. C. Sherman.

No. 136. Ammonia in Milk and its Development during Proteolysis under the Influence of Strong Antiseptics. By H. C. Sherman, W. N. Berg, L. J. Cohen and W. G. Whitman.

C. F. C.

DEPARTMENT OF CIVIL ENGINEERING.

The third annual dinner of the graduate civil engineers of Columbia University was held Saturday evening, April 13, at the Hotel Astor. The men gathered together there represented graduates of the various classes from the earliest to 1906, and numbered not less than 125.

The toast-master of the evening, Mr. Daniel E. Moran, class of '84, introduced the following speakers of the evening: Dr. Rudolf Tombo, Jr., Adjunct Professor of Germanics and Registrar of the University; Mr. Nelson P. Lewis, C.E., Chief Engineer of the Board of Estimate and Apportionment; the Hon. David J. McClure, the Hon. Job Hedges, and Professor Wm. H. Burr, head of the Department of Civil Engineering.

Probably the most important and interesting event of the evening was Professor Burr's announcement to the effect that the testing laboratory would after July 1, 1907, be transferred to and form a part of the Department of Civil Engineering.

In the future the department will be responsible for the testing work, and, under the reorganization, will also instruct all students in both resistance of materials and the theory of hydraulics. Those taking the latter will be required to spend some time in the hydraulic laboratory where experiments on the flow of the water will be undertaken. On the other hand, kinematics and the subject of pumps and pumping engines will be transferred to the Mechanical Engineering Department.

In the summer session at the University the Department will be represented by two courses, a new departure, one on Structures to be given by Professor Burr, and the other on Theoretical Hydraulics by Professor Wm. E. Mott, of the Massachusetts Institute of Technology.

The work at Camp Columbia begins June 1 and will be, as usual, under the direct supervision of Professor Lovell, who will have under him Mr. Sewall, '06 as principal assistant, Messrs. Finch, Bergman, Arnold and Carpenter, all Columbia men. The new house for the officers in charge will then be ready for occupancy, as will also the stone instrument house in which it is intended that all instruments be stored over night by the students after they have once drawn them from the supply room.

C. E. M.

DEPARTMENT OF ELECTRICAL ENGINEERING.

The department has become possessed, through a special appropriation made last year, of a large number of important electrical measuring instruments; also the following apparatus:

A motor generator set, consisting of a 15 h.p. 230 volt motor, and a three-phase 10 kilowatt generator.

A 5 h.p. single-phase motor.

A constant current transformer, with switchboard and lamps.

A general electric oscillograph, with which some very interesting work has been done.

A Leeds & Northrup potentiometer of the latest pattern, and

A number of standard watt-meters for the checking of consumers' meters under the contract which was made between the City and Columbia University.

The members of the senior class conducted theses on the following subjects: "Testing of Power Delivered to Arc Lamps on Municipal Light Circuits," "A Complete Test of a Three-phase Motor Dynamo Outfit," "Investigation and Test of a Single-phase Alternating Current Motor," "Relative Conductivity of Iron Cable for Direct and Alternating Currents," "A Study of Balance Equipments and New Type of Three-wire Generators," "The Determination of Acceleration Characteristics of Shop-motors as Controlled by Character of Load," "Coke and Carbon Resistance Furnaces."

The department has been presented, through the courtesy of Mr. August Belmont, with a motor generator set of 30 kilowatts capacity. This will be installed in the Alternating Current Laboratory, and ready for use by the opening of the next school year.

The second edition of Sever and Townsend's Laboratory Note-book has been issued, having been very carefully revised and brought up to date. Also Sever's Electrical Engineering Laboratory Note-book for the use of the engineering students other than those taking the electrical engineering course, has been carefully revised and rearranged.

Owing to the death of Mr. Fitzhugh Townsend, for nine years a tutor and instructor in this department, temporary arrangements had to be made to carry his work during this academic year.

G. F. SEVER.

DEPARTMENT OF METALLURGY.

The advanced courses in metallurgy consisting of about 60 more lectures in iron and steel and 60 in non-ferrous metallurgy, established in 1905, have now been tested and the result has justified the hopes entertained for them. Besides being required of students in metallurgy they have been elected in many instances by students in other departments. This is especially true of the advanced courses in iron and steel and in metallography. Two new courses have been established this year: Metallurgy 58, the metallography of iron, steel and other industrial alloys, a minimum of nine hours laboratory and three conferences (total, — not per week) under Dr. Campbell. Required of second year students in Civil Engineering and optional for all second, third and fourth year students in Applied Science. Metallurgy 176, the science of metallurgical investigation, ten afternoons conference under Professor Stoughton. The lectures in electrometallurgy have been increased to ten in view of the constantly increasing importance of this branch of industry. Dr. Kern gives this course. The number of non-ferrous lectures has been increased by fifteen, by adding one hour per week in the fourth year. Dr. William Campbell has been advanced to be adjunct professor of metallography. Messrs. Frank Firmstone and F. Louis Grammer, consulting engineers, Mr. R. A. Hadfield, President of the Iron and Steel Institute of London and Dr. R. W. Raymond, Secretary of the American Institute of Mining Engineers, lectured before different classes in metallurgy.

The Czar of Russia has created Professor Howe Knight of St. Stanislas, and conferred upon him the cross of the second order and the star of the first order. Professors Howe and Campbell are members of the

Committee on Corrosion of Iron and Steel of the American Society for Testing Materials, and together form the Subcommittee on Microstructure. Professor Campbell has been elected Secretary of the section of Astronomy, Chemistry and Physics of the New York Academy of Sciences, and has been appointed Metallographer of the Division of Structural Materials of the U. S. Geological Survey.

A laboratory of electrometallurgy has been established under Dr. Kern. Besides the apparatus for electric smelting, refining and testing already owned, the following has been added: Six 144-ampere-hour "Bijur High Duty" storage cells; switch board for connecting these in any desired combination to give current of 10 to 100 amperes at 2 to 12 volts; four Weston standard ammeters for 5 to 50 amperes capacity, and two voltmeters of varying delicacy; rheostats, etc. Current up to 500 amperes at 220 volts can be drawn from the University power circuit. To the metallographic laboratories have been added: One Chatelier and six Leitz microscopes for examination and photomicrography; desk galvanometers and couples for pyrometry; a Wanner and a Féry optical pyrometer; a recording thermo-electric pyrometer; standard thermo-couples for checking and calibrating pyrometers; Sauveur specimen cabinet; polishing and emery wheels; etc. Two complete experimental cyanide plants have been installed.

Professor Howe is continuing his investigation of the segregation and piping of steel ingots under the auspices of the Carnegie Institution of Washington, and, with Professor Stoughton, the segregation and piping of wax ingots and the relative corrosion of iron and steel. With Professor Stoughton and Mr. G. Rocour, candidate for the degree of Met.E., he is investigating the heat treatment of a 0.50 per cent. carbon steel, and, with Dr. Kern and Mr. A. W. Newberry, candidate for the degree of Met.E., he is investigating the expulsion of arsenic from arsenopyrite by roasting. Professor Stoughton superintended the first operations of a steel plant designed by him at McKeesport, Penna. With Mr. G. L. Fliessner, candidate for the degree of E.M., he has been investigating the mutual solubility of Fe, FeS, Cu, Cu_2S. Professor Campbell has been investigating the structure of mattes, speisses and other furnace products and the heat treatment of steel, the latter being for the Carnegie Institution, Washington. With Mr. F. Lage, candidate for the degree of Met.E., he has investigated the rolling temperatures of rail steel, and with Mr. G. H. Kingsbury, candidate for the degree of A.M., alloys of copper and copper sulphide. Dr. Kern has investigated the electrolysis of metallic sulphides in fused electrolytes, the electrolytic refining of iron, the electrolytic treatment of lead-zinc ores for the recovery of their metallic content and the production of copper-vanadium alloys. With Mr. F. G. Fabian, candidate for the degree of E.M., he is investigating the electrolytic precipitation of nickel in a solid and coherent form and, with Mr. R. P. Jarvis, candidate for the degree of Ph.D., the influence of the presence of certain reagents upon the density and coherence of electro-deposited copper, lead and silver.

Professor Stoughton has twice delivered his course of extension lectures on the metallurgy of iron and steel of the Department of Educa-

tion of the City of New York. Dr. Campbell gave an exhibition of microscopic metallography with illustrative enlargements at the Twentieth Annual Exhibition of the Department of Microscopy of the Brooklyn Institute of Arts and Sciences.

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DEPARTMENT OF MINERALOGY.

During the past year fifteen new species and a number of rare and fine minerals have been added to the Egleston Museum. Exchanges of minerals have been made with the New York State Museum and private collectors, resulting in the addition of much valuable material. The total value of the collection has increased, but the number of specimens remains about the same, due to the necessary removal of material for use in the student work. The projection lantern has been greatly improved and apparatus secured for the microscopic examination of opaque minerals by incident reflected light. The conference and student mineral collections have been also materially bettered, and purchases have been made of minerals at pound rates for determinative work.

Mr. C. A. Stewart, A.B., has been appointed assistant in mineralogy in place of Mr. J. E. Sinclair resigned.

An exhibition of newly acquired student apparatus and minerals was made at the New York Academy of Sciences meeting held in the American Museum of Natural History during December and January, 1906–'07.

A new course in mineralogy and crystallography has been arranged for all students, candidates for the degree of chemist. This course (Min. 7–8) covers much the same ground as was contained in the course in descriptive and determinative mineralogy (Min. 1–2), formerly taken by the chemists, but with a substitution of some measurement of crystals and the determination of optical constants of crystals for part of the usual work. The old course in physical crystallography (Min. 8), for second year chemists, has been stopped to make time for electrochemistry.

The proposed change in the Schools of Applied Science, by which the work in the first years is to be made uniform for all courses, will result in putting the present first year courses in mineralogy into the second year. This should result in better work in mineralogy being accomplished by the students.

Professor Moses has been investigating the composition and crystallization of stephanite and polybasite and their mutual relations, and is also describing some new types of beryls. In connection with Mr. Lamme an elaborate research is under way on the effects of temperature on the crystallization of certain chemical compounds.

Professor Luquer is studying the effects of high temperature as obtained with an oxygen-gas blowpipe on the commonly called infusible minerals.

Mr. Lamme is continuing his research work on the volumetric determination of antimony by sodium thiosulphate.

Mr. Stewart has been studying the magnetite deposits of Putnam County, N. Y. Particular attention has been given to the structure and mineralogy of the wall rock in an attempt to find some evidence regarding the origin of the ore.

Mr. Lincoln, graduate student, has been working on the determination of the more common opaque minerals in polished surfaces, especially upon the characteristic appearances of the various minerals as observed under the microscope by reflected light and after chemical tests applied directly to the polished surfaces. A table is being devised in which the opaque minerals are differentiated by color, hardness, crystalline outlines, cleavage, structure and association. The chemical tests found to be of greatest value in differentiation are treatment with different strengths of nitric and hydrochloric acids, with potassium hydroxide, with bromine, and with zinc amalgam. In special cases other tests were employed. The results of this research will be published shortly.

Mr. Latham, special student, has prepared a paper describing the rediscovery of one of the historic localities of emerald in Colombia.

A. J. M.

BOOK REVIEWS.

The Principles of Copper Smelting. By EDWARD DYER PETERS, Professor of Metallurgy, Harvard University. Hill Publishing Company, New York, 1907. Pp. viii + 569. Sixteen illustrations and many tables. Price $5.00.

This important new work by Dr. Peters reached us too late for notice in our April issue. It supplements the author's previous treatise on "Modern Copper Smelting," in dealing chiefly with the chemistry and principles upon which the different methods of smelting are based. Details of plant and practice are discussed only so far as is necessary to illustrate the application of the principles. While constant reference is made to the operations as conducted under varying conditions at existing plants, the author's object as stated in the preface is to present the *reasons why* instead of the *means how*.

The book is divided into the following chapters: I., Methods and Collectors; II., First Principles of Smelting; III., The Principles of Roasting; IV., The Chemistry of Smelting; V., The Practice of Roasting; VI., Blast Furnace Smelting; VII., Reverberatory Smelting; VIII., Pyrite Smelting; IX., A Practical Study of Slags; X., Matte; XI., The Production of Metallic Copper from Matte; XII., The Refining of Copper; XIII., The Principles of Furnace Building; XIV., Applications of Thermochemistry; XV., Miscellaneous and Commercial.

In the first chapter are a few brief but pointed remarks on the wet methods of extracting copper. These, formerly of great importance, are now generally superseded everywhere by smelting, the only prominent and successful exception to the rule being found in the Rio Tinto district in southern Spain, where peculiarly favorable conditions for leaching prevail.

The underlying principles of copper smelting are first set forth by a discussion of the behavior in the blast furnace of several different ores of typical character. After adducing the causes of the imperfect results, both technical and commercial, obtained from many ores by direct smelting, the principles of roasting are explained, followed by a study of the chemical reactions and physical changes taking place in the roasting of those sulphides which the metallurgist is usually called upon to treat. The author here makes a clear distinction between certain more or less complicated intermediary reactions, such as those in which sulphur trioxide plays so important a part, and the final results sought for. At this point instead of proceeding at once to a discussion of the practice of roasting a chapter is introduced on the chemistry of smelting. The fundamental laws governing the formation of matte and slag are set forth and the modifications necessary in applying them in practice are illustrated by the working out of several examples. This chapter is in many respects the most important and valuable in the book and presents a rather difficult subject in a manner readily intelligible to the student of metallurgy.

The deferred discussion of the practice of roasting is next taken up. It treats of the methods and the preparation of the ore and traces the development of the modern roasting furnace. The characteristics of the principal types of furnace now in use are briefly summarized, chiefly with respect to their mode of operation and to the results obtained. Full details of construction are properly omitted in a treatise of this kind.

Chapters VI. and VII., The Blast Furnace and Reverberatory Smelting, contain first a detailed study of the principles of operation and the reactions produced in the furnaces, and second, an historical résumé of the successive improvements in the design and construction which have culminated in the huge furnaces introduced in recent years. A good reduction of the working drawings of a modern furnace with some of the principal dimensions is given by way of illustration, together with a somewhat detailed description of the new and large water-jackets of the Washoe smelter, Anaconda.

Under reverberatory work Dr. Peters gives a clear and almost minute exposition of the application of principle, and of the practical operation of this type of copper reduction. He discusses the mode of firing and of regulating the draft, the effects of radiation of heat through walls, roof and hearth, and the means by which loss of heat may be minimized in the management of the furnace.

The chapter on Pyrite Smelting is the longest in the book, covering about 125 pages. Much interest in this branch of smelting was evoked by the lengthy discussion of the subject in the *Engineering and Mining Journal* in 1904 and 1905, and the subsequent publication of the same in book form by T. A. Rickard. Dr. Peters himself made an important contribution to this discussion in the form of a review of the opinions advanced by other metallurgists as to sundry debatable points. In the present work which is intended primarily for students the author takes up the subject from quite a different viewpoint. The conditions necessary to success are first stated, including the constitution of the ore and the important matter of the time-element; then follows in much detail the chemistry of the process and the questions of quantity of air required and the formation of the slag. The nature of the slag produced in pyrite smelting is explained, while showing, as previously pointed out by Carpenter and Sticht, that "the pyrite furnace chooses its own slag." After commenting on the uncertainty as to just what kind of slag will be formed under normal conditions the author quotes at great length from Sticht's discussion of the matter in *Metallurgie*, 1906. Then follows (page 283) a study of the phenomena occurring "when the conditions are *not* normal and the constituents of the charge are *not* properly proportioned to one another." These considerations are developed throughout the remainder of this interesting chapter with frequent quotations from Sticht's authoritative monograph and reference to the practice at Mt. Lyell.

A "Practical Study of Slags" from the standpoint of the copper smelter is taken up in some sixty pages in Chapter IX. It is illustrated by many examples to show how the calculations are made and to explain chemically the influence and fluxing values of the different con-

stituents of the charge. Many tables including a number by Hofman, are inserted, intended to facilitate slag calculations and to show the effect of variations in composition of the charge.

The next three chapters, occupying about 100 pages, are devoted to mattes; the production of metallic copper from them and the refining of copper. In introducing the second of these three topics the author makes the following significant remark: Hitherto "the student . . . . has been occupied largely with slags and has given comparatively little heed to the available constituents of his charge, feeling sure that if his slag possessed reasonable liquidity and specific gravity his properly sulphidized metals would separate therefrom in the form of matte, without special attention other than that required to provide a suitable vessel in which the fusion products might arrange themselves according to the law of gravity." This prepares the way for a consideration of the further treatment of that small part of the original charge which is transformed into matte; a subject which is developed with the author's customary lucidity. Each of the rather numerous processes for the separation of the precious metals from copper is summarized, closing with a good description of the bessemerizing of copper matte. The chapter on refining concludes the author's treatment of his main subject. Three more chapters are added, however, in which are discussed the principles of furnace building (with many details as to the materials employed, and the location of furnaces with a view to the proper disposal of their products); the applications of thermo-chemistry to furnace work (prepared for this book by Professor Joseph W. Richards), and sundry miscellaneous and commercial matters relative to copper smelting. A very full index of some forty pages is supplied.

This work is an important contribution to the subject of copper smelting, well adapted alike to the needs of the student and the practiced metallurgist. R. P.

Hydro-metallurgy of Silver, with special reference to the Chloridizing Roasting of Silver Ores and the Extraction of Silver by Hyposulphite and Cyanide Solution. By OTTOKAR HOFMANN, Mining and Metallurgical Engineer, etc. New York, Hill Publishing Company, 1907. Pp. 345, 83 illustrations. Price $4.00.

In these days the metallurgy of silver as a distinct process has lost some of its former importance. The mining and extraction of gold and copper in the past twenty years have come to occupy relatively more attention in the mining world and silver relatively less. It is probable that more silver is produced now than formerly as a by-product of the metallurgy of other metals: as one of several products of the smelting of lead-silver or of complex ores, or as a secondary product of the cyanidation of gold-silver ores. Pan-amalgamation, with or without preliminary chloridizing roasting, once so important is now rarely used; and lixiviation with sodium hyposulphite has lost some of its prestige at least as a primary extraction process.

Nevertheless, some of the wet methods are still the chief dependence of metallurgists for the separation of silver from certain dry ores or from matte; and the cyanidation of gold-silver ores, even when the

silver is the principal value (witness the recent successful application of the process at Palmarejo, Mexico, and in Western Australia, New Zealand and elsewhere), has of late years attained considerable prominence.

Ottokar Hofmann is a metallurgist of long and varied experience in the reduction of the precious metals and his book will be read with profit by all interested in this branch of the art.

The work is divided into two parts: Chloridizing Roasting of Silver Ores and the Methods of Extracting the Silver. The subject of roasting occupies some 150 pages and a large amount of detail is given respecting methods of roasting ores of different characters, the loss of silver by volatilization, the collection of flue dust and the operation of reverberatory and mechanical roasting furnaces. The long chapter on Chloridizing of Argentiferous Zinc-lead Ore consists mainly of the author's records of investigations on the ore of the San Francisco del Oro mine, near Parral, Chihuahua, and contains much suggestive and useful matter. Chapter XII. comprises similar records of successful work in improving the results obtained from the roasting of the highly calcareous ores of the Anglo-Mexican Mining Company at Yedras, Sinaloa. Mr. Hofmann's account of his work at the Silver King mine, of Arizona, has been read with peculiar interest by the writer of this notice, who years ago had some part in the metallurgical operations at that mine when the character of the ore had so far changed that the leaching process previously introduced by Mr. Hofmann no longer served its purpose.

In the second part of the book an extended description is given of lixiviation with sodium hyposulphite and the precipitation and the treatment of the precipitate; followed by an account of "trough lixiviation," with details of its application at the old Cusihuiriachic mine, Chihuahua.

Brief mention is made in Chapters XVIII. and XIX. of the Russell, Kiss and Augustin process. In Chapter XX. the sulphuric acid process of extracting silver from matte and other similar products is described at considerable length.

The last chapter on "Cyanidation of Auriferous Silver Ores" consists largely of abstracts of several recent and valuable papers on this subject, with comments by the author.

Those parts of the book — and there are many of them — which consist of accounts of the author's own experiences in the field are of special interest. As he himself says, much of the matter presented is a record of his "studies and experiments on a commercial scale rather than the product of compilation." He has, moreover, been identified with the design and erection of reduction works at many of the important mines in this country and in Mexico, and has exerted no small influence in the development of his chosen branch of metallurgy.

R. P.

Rock Minerals: Their Chemical and Physical Characters and their Determination in Thin Sections. By JOSEPH P. IDDINGS. New York, John Wiley & Sons, 1906. 8vo, pp. xii + 548, 438 figures and one colored plate. Cloth, $5.00.

In 1888 Professor Iddings translated and abridged "Rosenbusch's Mikroskopische Physiographie der petrographisch wichtigen Mineralien," the fourth edition of which appeared in 1900. Professor Iddings now earns the gratitude of all English-speaking petrographers and mineralogists by producing the results of his long experience in a definitely independent work which, while it does not claim to possess the completeness of the later editions of the great German work, is nevertheless so detailed that it is fairly to be called a book of reference for the skilled petrographer.

The work begins with a review of elementary principles in chemistry affecting an understanding of the composition of minerals. No attempt is made to describe methods of analysis, but some pages are devoted to discussions of preparation of material for these analyses, such as specific gravity and magnetic separations, and also to the chemical tests upon thin sections.

Chapter II. considers principally the molecular structure of crystals and its effects upon density and form, and then passes to a brief consideration of crystal symmetry forms, classes and symbols. The Miller symbols are used and the Groth classes. The convenient terms, euhedral, subhedral and anhedral, are adopted for well developed, poorly developed and faceless crystals. Whether, however, there is anything gained by the adoption of the Groth form-names of pedion, pinacoid, dome, sphenoid, bisphenoid, prism and pyramid, rather than the more generally used names, is to be questioned.

Although the laws affecting crystal "habit" are not well known, the author discusses the probable effects of surface tension, diffusion currents and molecular forces and reaches interesting conclusions. Similarly his summation of the known facts as to liquid and solid inclusions is very interesting reading.

In Chapter III. the author "reviews the optical principles and describes at considerable length the interference phenomena that become diagnostic characters of the rock minerals." This of course is the most important portion of the work, as upon it rests the proper understanding of the principal tests of the petrographer. It commences with the fundamental principles of the undulatory theory of light, reflection, refraction, total reflection, lenses, microscopes, etc., and then considers approximate methods of determining indices of refraction which are available in petrographic work, giving preference to the Becke test and the Schroeder van der Kolk use of liquids, but not favoring the de Chaulnes or Viola methods. The more exact methods are referred to, but not described.

The discussion of polarized light and its production is adequate and is followed by the methods of using it in proving the properties of doubly refracting crystals. There are admirable figures explaining the convergent light tests and an especially convenient method, p. 180, for determining the optical character of a biaxial crystal in a plate normal to the optic axis.

"The second part of the book contains descriptions of the better known rock minerals," the term being used to include all primary minerals, and all those of secondary origin produced by any manner of alteration of previously existing minerals, but not including certain classes of vein minerals such as those of ore veins.

The order of presentation is chemical and petrographic, silicates first but, for instance, poly, meta, and orthosilicates of the same bases may be together. The treatment is very comprehensive, each species being considered under the following headings:

Chemical Composition, Alteration, Crystallographic Characters, Optical Properties, Modes of Occurrence, Resemblances to Other Minerals, Laboratory Production.

An idea of the thoroughness of the presentation may be had from the fact that the discussion of the pyroxene group occupies 45 pages.

The last fifteen pages of the book contain the Tables of the Optical Characteristics of the Rock Minerals, classified as Isotropic, Uniaxial, and Biaxial. Under each the order of arrangement is primarily by indices of refraction in similar groups.

These tables are rather a summation than a scheme and might well be preceded by a scheme, involving the more important species. A colored plate showing the interference colors and birefringence of the rock minerals which is essentially the same as that in *Les Mineraux des roches* of Levy and Lacroix follows the index.

The book is well printed and bound and is undoubtedly an essential tool for all petrographers and mineralogists.

A. J. M.

Das Erdöl und seine Verwandten. By HANS HÖFER, Privy Councillor and Professor in the Mining Academy of Leoben, Austria. 8vo, pp. xvii + 258. Unbound, 10 marks. Braunschweig, Friedr. Vieweg & Sohn, 1906.

This excellent little manual of petroleum, natural gas, ozokerite and asphalt is the result of many years of study and investigation. Professor Höfer's experience has been gathered in America as well as Europe. Thirty years ago he was one of the foreign judges at the Centennial Exposition in Philadelphia and subsequently traveled extensively in North America. On his return two volumes resulted; one on the Coal and Iron Deposits* and a second on the Petroleum Industry.†

The book opens with a brief outline of the classification of the minerals treated of which there are five: (1) Gases, next fluids, including, (2) Petroleum, and (3) Maltha. Lastly solids, embracing, (4) Ozokerite, (5) Natural pitch (Erdpech can be kneaded) and (6) Asphalt (brittle). This classification is not essentially different from the one generally in use in America, except that asphalt is not restricted here to brittle substances. Mixtures of the above with coals and rocks proper are also defined.

* Die Kohlen- und Eisenerz-Lagerstätten Nord-Amerikas," Vienna, 1878.

† Die Petroleum-Industrie Nord-Amerikas," *Wagners Berichte*, 1877, 1026.

A very interesting historical sketch of the ancient and modern uses and of the better known districts constitutes Chapter II. One or two not unimportant localities are missing from the list, such as Sumatra and Peru. Chapter III. deals with the physical and physiological properties, and Chapter IV. with the chemical composition. After these, the occurrence, the origin, the discovery and production, and lastly the statistics are successively taken up.

Under Chapter V. on the occurrence of the minerals, the deposits are divided into primary; or those original in the strata where found; and secondary or those derived from a distance. The conceptions of natural storage which have been advanced by various writers are discussed in a very interesting manner. It is presumably not generally realized in America that Profe·sor Höfer remarked the association of the oil-pools with the anticlines in Pennsylvania, as far back as 1876, and mentions this in his book or report upon the oil industry as earlier cited. The present book was prepared in the belief that he himself had originated the idea. While reading the proofs, however, he noted that the late T. Sterry Hunt had remarked the same as far back as 1867. Professor Höfer very handsomely then credits Dr. Hunt with the first observation (p. 135). The records go however much farther back, since in the *American Journal of Science* for July, 1861 (vol. xxxii., pp. 88–90), E. B. Andrews not only notes the occurrence of oil beneath the anticlines but supports his contention by seven sections and profiles. The great revival of this old-time view, but with new conceptions of storage, by I. C. White and Edward Orton about 1890 is one of the most interesting facts of modern geology and was what gave the idea its great practical value and use by the prospectors.

Professor Höfer's work places in the hands of all who need a condensed and modern manual a very valuable work. J. F. K.

Die Untersuchung des Erdöles und seine Producte. By M. A. RAKUSIN, Chemist and Engineer in the petroleum industry of Moskow. Braunschweig, Friedrich Viewig & Son, 1906. 8vo, pp. xviii + 271, 59 figures. Price, unbound, 12 marks; bound, 13 marks.

This volume is an important addition to the rather meagre modern literature on the examination of petroleum oils and will be useful to all who have to do with this industry, whether employed in the laboratory or in the works. The principal topics treated are: (1) General methods, such as determination of water and mechanical impurities, specific gravity and coefficient of expansion, flashing and burning points, proximate and ultimate composition, calorific power, and solvent properties — 115 pages. (2) Special methods, including photometric and colorimetric tests of burning oils, the examination of lubricating oils, and tests of purity of refined products — 54 pages. (3) "New methods," consisting of an outline of Lidoff's scheme of analysis and a full discussion of the examination of mineral oils by means of polarized light — 32 pages. (4) Methods and data concerning the storage and control of petroleum products — 20 pages. (5) Tables, literature, index, etc. — 50 pages.

The text is freely supplemented with excellent figures and with tab-

ulations of valuable data, many of which are not readily available elsewhere. An especially noteworthy feature is the explicit manner in which methods and apparatus are described and the large number of special devices and procedures for the examinatien of particular products. For example, under methods for specific gravity determination procedures are given for gases, semi-solids, and solids as well as for liquids and the coefficients of expansion for petroleum products of different origin and density are given in unusual detail. Most of the other subjects treated are discussed with similar completeness. Tabulations of illustrative analytical data cover petroleum products from many different localities, and often the corresponding figures for fatty oils are given for comparison.

Although written largely from the standpoint of the Russian oil industry, the treatment is so broad and thorough that the work should be almost as useful in America as in Europe. H. C. S.

The Seven Follies of Science. A popular account of the most famous scientific impossibilities and the attempts which have been made to solve them. By JOHN PHIN. Second edition. New York, Van Nostrand Company, 1906. Price $1.25 net.

This book reviews in a popular, delightful, and yet scientific manner, the attempts which have been made to solve those scientific problems which have come to be regarded by men of science as impossible of solution. That the things discussed are of vital import to science does not perhaps strike one immediately, but nevertheless they are. The long and vain search for a perpetual motion has resulted in the formulation of the two fundamental principles of thermodynamics, and the futile attempt to transmute base metals into gold has led to our present concept of chemical element. In each case it is solely a question of experience. Neither in itself was absurd. There is no reason which would prevent the existence of a perpetual motion, *except that the experience of ages shows it to be impossible*, and so we say a perpetual motion of whatever kind is impossible. In the same way, although there is no reason which would prevent the transmutation of one element into another, *experience shows it to be impossible.* It is only a question of experience in both cases, then, and in this respect the book actually becomes in a way a history of science; and in this spirit it should be read by everyone interested in science.

J. LIVINGSTON R. MORGAN.

Elements of Gas Engine Design. By SANFORD A. MOSS, M.S., Ph.D., Member of the A. S. M. E., Engineer, General Electric Co., former Instructor in Machine Design in Cornell University. Van Nostrand Science Series, No. 121. New York, D. Van Nostrand Co. 50 cents.

The title of this book is quite pretentious for so small a volume and is apt to be misleading except perhaps when emphasis is put upon the first word, "Elements." It is a curious mixture of basic scientific facts and arbitrary empiric statements, such as must always be the result of an attempt to concentrate in a small book of this size material of so

broad a scope as the design of the modern gas engine. With this limitation the work is probably as well done as possible, but it is difficult to see what needs it would fill since it offers no help to a designer and is too narrow and misleading for a student. The reader who wants simple rules will find them here, but he will find no attempt to guide or guard him in the use of these rules, so that there is a probability of their being misused. The subject is entirely too complex to permit of reduction to simple rules, depending as it does upon so great a variety of conditions sometimes difficult to define. There are many errors in the book, of which Fig. 5, is a fair example. This cut is supposed to be an indicator diagram and yet the suction, compression and exhaust strokes are longer than the expansion stroke, which, of course, is impossible. C. E. L.

Four Centuries of the Panama Canal. By WILLIS FLETCHER JOHNSON. New York, Henry Holt & Co., 1906.

As the author states in the preface, his object is to tell the story of the canal, and incidentally that of Panama in so far as it relates to the former, from the time of Christopher Columbus to Theodore Rosevelt. Beginning with the earliest Spanish explorations there is traced through the succeeding centuries the development of the idea which in a few years promises to be a fact. The first conception of a canal is assigned to Alvaro de Saavedra Ceron, a cousin of Cortez, who in 1529 prepared plans for the construction of one in that region which plans he proposed presenting to the king of Spain. The principal events associated with the growth of this idea, and the influences working to bring about this great undertaking are recorded, showing the place Nicaragua has occupied in the canal scheme; the preponderance of evidence in favor of Panama; the work of the French company under de Lessups, with its failure, mistakes, and final disaster.

Some pains are taken in showing that the position the United States has assumed in the project has always been a legitimate and humanitarian one, and particularly in demonstrating the justification of its acts with Colombia and Panama at the founding of the Republic. About one-third of the book is devoted to the work that has been accomplished in the past few years, with a description of the activities at present.

C. E. M.

Sewage and Sewage Disposal. By Professor HENRY ROBINSON. London, Biggs & Co.

This is a work of some 195 pages, treating in 16 chapters the subjects of House Drainage, Trades Wastes, River Pollution, Irrigation, Precipitation, Sludge, Filtration, Contact and Percolating Beds. The book from the standpoint of general information has some value, but contains too little of an exact and positive information, and covers too broad a field to be of much service to the engineer. Thus the subject of Irrigation is disposed of in about seven pages, while "Contact Beds" receives but little more.

C. E. M.

Mechanics Problems. By FRANK S. SANBORN. New York, Wiley & Sons. Pp. 194.

This book of about 200 pages, containing 600 problems in mechanics, for students, can be most highly recommended. While there is nothing essentially new in the collecting of such problems, it emphasizes the fact that to appreciate the value of mechanics the student must be able to apply the theory to practice. The work is divided into three parts, with review problems at the end.

Part I. devotes 172 problems to Work; Part II. describes the topic Force, while Part III. treats of Motion.

At the beginning of each section a sample problem is worked out to explain the method of solution, and serve as a guide; and the answers to most of the problems are to be found at the end of the book. The author in the introduction says: "In engineering practice one is often puzzled to tell just what data to collect and afterward how much of it to use; because of this I have left more data in some of the problems, that the student will have the opportunity to pick and choose, just as in actual cases." C. E. M.

The Construction and Care of Brick Pavements. By IRA O. BAKER. A reprint from the *Clay Record*, Chicago. Pp. 24.

The above reprint from the *Clay Record* of October 30, 1906, forms part of the report on the "Paving Brick Industry of Illinois," issued by the State Geological Survey. It is intended for the property-holder and layman, and the subjects are taken up approximately in the order in which they occur in the work of construction. The subjects treated are the brick pavement, width, subgrade, foundations of gravel, brick, concrete, etc., the testing of brick, and the joint filling.

C. E. M.

Chemical Abstracts. Published semi-monthly by the American Chemical Society through the Chemical Publishing Co., Easton, Pa. Edited by W. A. NOYES and C. E. WATERS, with the coöperation of a large staff of assistant editors and abstractors. Price $6.00 per annum.

In this journal, the first issue of which appeared with the beginning of 1907, the American Chemical Society proposes to publish abstracts of all investigations in pure or applied chemistry, wherever published. These abstracts are classified under the following sectional headings, each section being in charge of an expert in that particular branch of chemistry: Apparatus (Walker); General and Physical Chemistry (Lewis); Radioactivity (McCoy); Electrochemistry (Whitney); Photography (Friedburg); Inorganic Chemistry (Smith); Analytical Chemistry (Dennis); Mineralogical and Geological Chemistry (Hillebrand); Metallurgy (Richards); Organic Chemistry (Bogert); Biological Chemistry (Mendel); Foods (Bigelow); Nutrition (Langworthy); Water, Sewage and Sanitation (Kinnicutt); Soils and Fertilizers (Veitch); Fermented and Distilled Liquors (Wahl); Pharmaceutical Chemistry (Stevens); Acids, Alkalies and Salts (Briggs); Glass and Pottery (Barton and Bleininger); Cements and Mortars

(Drew); Fuel, Gas and Coke (Pennock); Petroleum, Asphalt and Wood Products (Sadtler); Cellulose and Paper (Little); Explosives (Munroe); Dyes, Bleaching and Textile Fabrics (Olney); Pigments, Resins, Varnishes and India Rubber (Sabin); Fats, Fatty Oils and Soap (Richardson); Sugar, Starch and Gums (Browne); Leather; Patents (U. S., British, German and French) (Seaman).

Chemical Abstracts is intended to present the most complete record of the progress of chemistry in the world, equalling the *Chemisches Zentralblatt* in the field of pure science and excelling it on the technical side. That this ambition bids fair to be realized is evidenced by the fact that the issues for the first three months aggregate over 800 pages of about 700 words each.

Througn the coöperation of over 100 abstractors the Society is enabled both to keep the work very nearly up to date and to supply it at a price which would not have been thought possible. Members receive this publication in addition to the Journal of the Society, paying dues of eight dollars a year, and as membership is not limited to professional chemists it is probable that many who are more interested in the applications of chemistry than in the progress of the science itself will now be led to join the Society.

The mechanical makeup of the work is excellent and it is probable that a further convenience will be offered in the publication of the abstracts on one side of paper only for those who desire to file them in indexes. A more extended and systematic use of abbreviations would, however, make it possible to present a more complete and serviceable abstract of any given article in the same amount of space.

H. C. S.

Van Nostrand's Chemical Annual, 1907. A Handbook of Useful Data for Analytical, Manufacturing, and Investigating Chemists and Chemical Students. Edited by JOHN C. OLSEN, A.M., Ph.D. New York, D. Van Nostrand Company. Pp. x + 496. Price, $2.50 net.

This volume, which is to some extent based upon Biedermann's Chemiker Kalendar but in many respects is an entirely independent work, includes both an extended compilation of numerical data and a guide to recent chemical literature. In the former part of the work Professor Olsen has been assisted by Albert F. Seeker, E. Emett Reid, and C. A. F. Kahlbaum; in the latter by Allan Rogers, Victor J. Chambers, J. L. R. Morgan, George B. Pegram, and Carl H. Lips.

The first part of the work includes tables of atomic weights, periodic system, densities of gases, physical constants of elements, factors and their logarithms; data for the calculations of volumetric analysis, physical and chemical constants of oils, fats and waxes, temperature corrections for refractive indices and densities of oils, reduction of gas volumes, logarithms of numbers, physical constants of inorganic and of organic compounds, specific gravities, vapor tensions, equivalents of weights and measures, and heats of combustion.

The atomic weights given are those adapted for 1906 by the International Committee, and these are used in the calculation of all molec-

ular weights and factors for the calculation of analytical results. The latter are quite complete and are carried out to five decimal places so that each user may round off the figures to suit the accuracy of the work in hand.

The tables of physical constants of compounds, and the specific gravity tables for acids, bases and salts are also quite extended. The latter include both Ferguson's and Lunge's tables for sulphuric, nitric, and hydrochloric acids. It is stated that wherever the Baumé scales are used they have been calculated from the specific gravities according to the so-called American standard:

Baumé = 145 — 145/sp. gr. for liquids heavier than water.

Baumé = 140/sp. gr. — 130 for liquids lighter than water.

Excepting the calorific powers of fuels, the data given seem to be taken largely from original sources brought well up to date. The sequence of subjects does not always seem logical and the group headings in the table of contents are in some cases misleading (*e. g.*, the general tables of logarithms and of physical constants of compounds are entered under the heading "calculations of gas analysis") but this is of less importance since the book is provided with an index.

The second part of the work is devoted to recent chemical literature and contains lists of books and journal articles published between January 1, 1905, and June 1, 1906. The index of journal articles covers over 1,000 titles grouped under the following divisions in charge of the editors indicated: Analytical Chemistry (Olsen); General Inorganic Chemistry (Olsen); Industrial Chemistry (Rogers); Organic Chemistry (Chambers); Physical Chemistry (Morgan); Radioactivity (Pegram). Under each division or subdivision the papers are listed alphabetically by subjects. The publishers are to be congratulated upon securing the coöperation of these editors.

The Chemical Annual will be found a most useful volume to all who have to do with chemistry or its applications.

H. C. S.

The School of Mines Quarterly.

Journal of Applied Science

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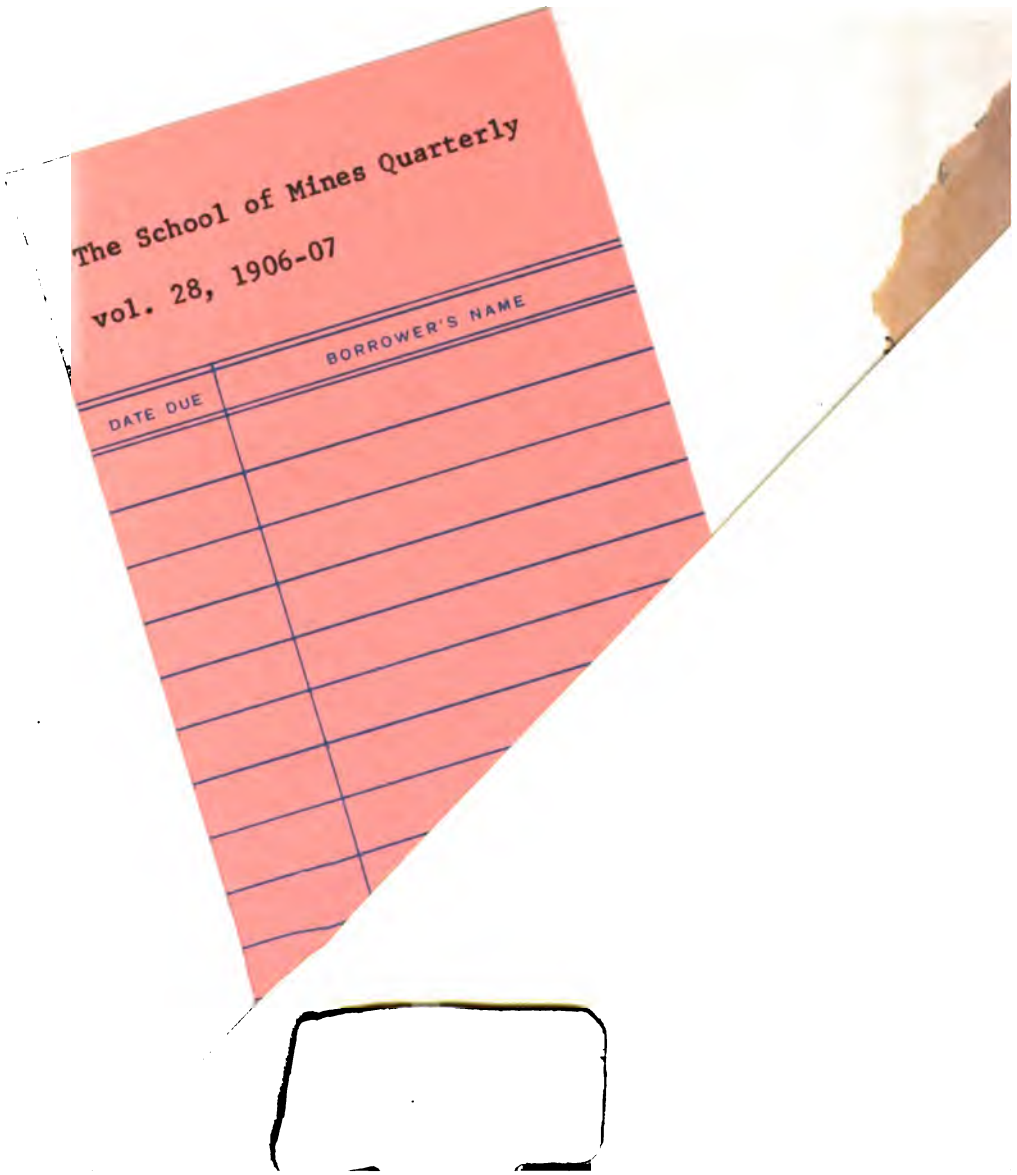
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